THINNING FOREST STANDS, WESTSIDE

An Inter-Active Self-Study and Reference Pamphlet

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Silviculture & Regeneration, Land Management Division
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NOTE: **DRAFT** WESTSIDE SELF-STUDY & REFERENCE MANUAL for THINNING as of 03/13/2006---Summary of current silviculture prescription training with examples, consistent with HCP, Forest Practices and DNR data technology. Expect frequent DRAFT updates, incl. changes, revisions, additions and/or cancellations.

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Notes to the Reader

- Electronic links are in blue underlined text and in Adobe format only accesses the desired page.
- This pamphlet is a part of the department's training and education program

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Preamble

[The HCP] allows timber harvesting and other management activities to continue while providing for species conservation [through special FMU and landscape objectives] as described in the [federal] Endangered Species Act.

The Habitat Conservation Plan
Introduction, p. I. 1

The Department will use . . . thinning . . . on stands which will respond and produce an acceptable rate of return on investment. . . . On some sites, the department intends to postpone precommercial thinning where it is biologically and economically beneficial to wait and conduct commercial thinning only.

Forest Resource Plan
Policy No. 34, p. 50

State trust lands are publicly owned and managed, but they are not "public lands" in the sense that we have grown accustomed to thinking about [federal] national parks and forests. ***They are . . . managed as trusts for clearly specified beneficiaries, principally the common schools*** *[emphasis added].*

Souder, Jon A. and Sally K. Fairfax. 1998.
State Trust Lands: History, Management, and Sustainable Use (p.285).
University Press, Lawrence, KS.

Intent

This is a self-study and reference pamphlet for field foresters . . .

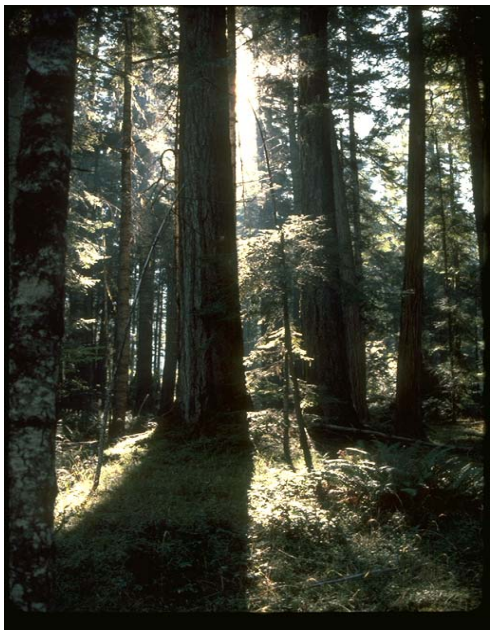
The intent of this publication is to provide a self-study and reference pamphlet for field foresters. The pamphlet will cover scientific theory as well as techniques and field craft for thinning forested trust lands. In brief, a decision to thin and how to thin a particular stand depends on the stand's biological capability to respond in a desired way to a thinning. That is, will thinning accelerate desired social, economic, and environmental objectives for the stand and landscape?

Scientific Theory Of Thinning

Thinnings accelerate and enhance natural processes . . .

As trees grow, competition gradually sharpens between individual trees for light, nutrients, and moisture. In time, natural "self-thinnings" will balance the number of stems with the capability of the site to support these needs (see picture on left). How well a site supplies the needed light, nutrients, and moisture i.e., site productivity, is often expressed height growth over time, or site index.

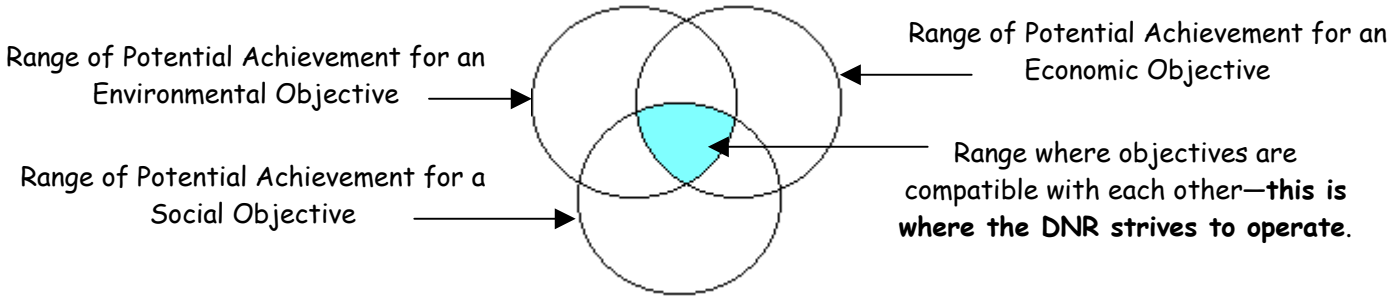
After several developmental stages, natural selection and stochastic events will generate diverse cohorts , particularly large standing and down dead trees (snags and large down woody debris—LDWD). The result is a complex multi-aged and -sized mosaic of high commercial, visual, and wildlife value (see picture on right). Objective-oriented thinnings accelerate, and sometimes enhance, these otherwise slow natural processes. We therefore prioritize stands that we thin to best attain objectives.



The purpose of thinning is to achieve social, environmental, and economic objectives . . .

The purpose of thinning is to achieve social, environmental, and economic rotational objectives for forest management units (FMUs) and management areas by accelerating stand development

processes. We do this by reducing the number of trees per acre and by enhancing important structural cohorts. FMU and landscape objectives derive from higher order plans, such as the DNR's Habitat Conservation Plan (HCP) for forested trust lands, as well as from public input, rules, and statutes. In managing trust lands, DNR categorizes objectives as social, economic, and environmental. The DNR manages its forests so that these objective categories will at least overlap, if not complement each other. The following figure illustrates the concept:



The shaded area in the center of the figure is where social, environmental, and economic objectives are in concert. This is where the DNR manages trust lands. Although DNR has a legal mandate to maximize financial revenues, financial gain has to be consistent with other legitimate objectives. Thus, financial gain may occasionally be sacrificed at the individual FMU level but not overall.

. . . FMU objectives must be measurable . . .

In order to be achievable and traceable, FMU objectives must be measurable. Thus, while a FMU objective consists of an action verb and an attribute (and sometimes a modifier), such as "achieve sub-mature habitat," components of the objective's attribute must be *discrete, measurable,* and *achievable* threshold targets, such as trees per acre, height, diameter, etc.

A silvicultural prescription justifies thinning . . .

A silvicultural prescription justifies thinning a particular stand. The silvicultural prescription represents the pathway of treatments that stand has to undergo in order to best attain its objectives. Thus, the process involves modeling the stand from its present stage through alternative regimes, or pathways, for the remainder of the rotation and performing financial analysis on each. By comparing how each regime, or pathway, satisfies social, environmental, and economic FMU objectives the best alternative will stand out. If, after mitigating for risk, the best regime calls for thinning, then the thinning is justified against FMU objectives; if not, then it should be abundantly clear that thinning is not justified. This approach applies pre-commercial thinning (PCT) and commercial thinning (CT), and for any stage of stand development. Silvicultural prescriptions is the only tool to ensure thinnings occur only where they accomplish social, environmental, and economic objectives better than other alternatives (including no action). Thus, overstocking alone is not a sufficient criterion to apply a thinning treatment.

. . . The Trust mandate has four ethical tenets . . .

The DNR's Trust mandate has four ethical tenets. These are (1) The Prudent Person Doctrine, (2) Undivided Loyalty to the Trust, (3) Intergenerational Equity, and (4) Do Not Foreclose Future Options. These tenets are ethical principles to be applied judiciously.

. . . forest stands go through a series of developmental stages

Between stand initiation and an older forest state, forest stands go through a series of developmental stages. In brief, they are: Stand initiation, competitive exclusion (iterations at sapling, pole, and large tree stages), understory development, botanically diverse/biomass accumulation, and niche diversification/fully functional.

In the picture below, front and center, is a plantation in the stand initiation stage. The plantation beyond has achieved crown closure and has probably entered the competitive exclusion stage for saplings and poles. The darker stand beyond the second plantation looks from a distance as if it might be in the understory development/biomass accumulation stages. The stand to the front right appears (varying tree heights, species, and crown cover) to be in the niche diversification stage.

Most scientific knowledge and mathematical modeling of stands has traditionally focused on the second, the competitive exclusion, stage. In this stage, forest stands consist of a single, usually even-aged canopy. Competition is evidenced by how much of the stem supports live green foliage i.e., crown ratio. The competitive exclusion stage may occur repeatedly as saplings, poles, and sawlog-sized trees grow.

Stochastic events (wind, fire, pathogen mortality) will at some time create openings of varying sizes in the dominant canopy. If the dominant cohort is beyond in-kind replacement, an understory will develop where direct light reaches the ground; this is the understory development stage.

As trees increase in size, live and eventually dead biomass accumulates. This in turn supports a proliferation of plant, fungal, and animal species as well as micro-biology. This is the botanically diverse, or biomass accumulation, stage.

As eventually trees become very large, so do snags and openings in the stand when trees fall. Emerging niche mosaics become increasingly textured and complex. Over time, niches sustain sufficient internal diversity and the stand sufficient diversity in niches to where habitat quality culminates. This is the niche diversification stage which merges into the fully functional stage.

Thinning reduces competition . . .

Thinning is a tool to accelerate stand development and achievement of FMU objectives. The science of thinning has traditionally focused on even-aged stands in the competitive exclusion stage. Universally, however, when a stand is thinned, lesser competition between trees is restored sooner than if nature were to "self thin" the stand. As a result, vigorous trees that are left after thinning approach a maximal rate of diameter growth. In contrast, self-thinning must wait until after competition for light, water, and/or nutrients has become sufficiently deleterious to result in the death of weakest trees. Release then occurs gradually, and growth rates in eventual leave trees are often less than maximal. High levels of competition may under some circumstances weaken the whole stand. Natural mortality can be hastened and increased if pathogens and/or drought overwhelm already weakened stands. Thus, even dominant trees may be weakened by competition and are then less apt to respond to thinning. The level of competition between trees should therefore always be a primary criterion for whether or not to thin a stand. This is particularly true for stands in the competitive exclusion stage. It is true but for more complex reasons when thinning in the later stages of stand development.

. . . both action and inaction have inherent risk . . .

Finally, both action and inaction have inherent risk. Neither thinning nor absence of thinning are exceptions. Here are some examples:

- On the coast, there is high risk of blowdown when thinning very dense stands in later competitive exclusion stages of shallow-rooted species, such as western hemlock.

- Most westside thinnings that remove more than 40 percent of the pre-thinning RD induce additional risk of blow-down, snow-breakage, and/or wind-shear, particularly if leave tree crown ratios are less than 35 percent (root/stem structure of weak trees being inferior).

- Westside thinnings that are done well prior to nearing the zone of imminent mortality (see page 5) induce risk of less value due to more and thicker branches and low form class.

- Elevated risk of annosum root rot (*Heterobasidion annosum*) is induced when western hemlock and/or Pacific silver fir stumps are cut shorter than 12 inches.

- Thinnings that alter stand composition from mixed to single species induce elevated risk of epidemic insects and disease outbreaks. (Conversely, thinnings that promote mixed stands reduce the risk of pathogen epidemics.)

- There is risk of damaged, or wrongly selected, leave trees through careless thinning operations as well as poor prescriptions.

However, we must also recognize another set of risks incurred by the absence of thinning. Examples are:

- pathogen epidemics brought on by stagnation

- foregone critical habitat

- foregone biodiversity

- foregone revenue

- foregone scenic values.

A stand that was thinned in the competitive exclusion stage. What potential thinning-induced risk factors do you see now, and what risks might have been incurred by not thinning?

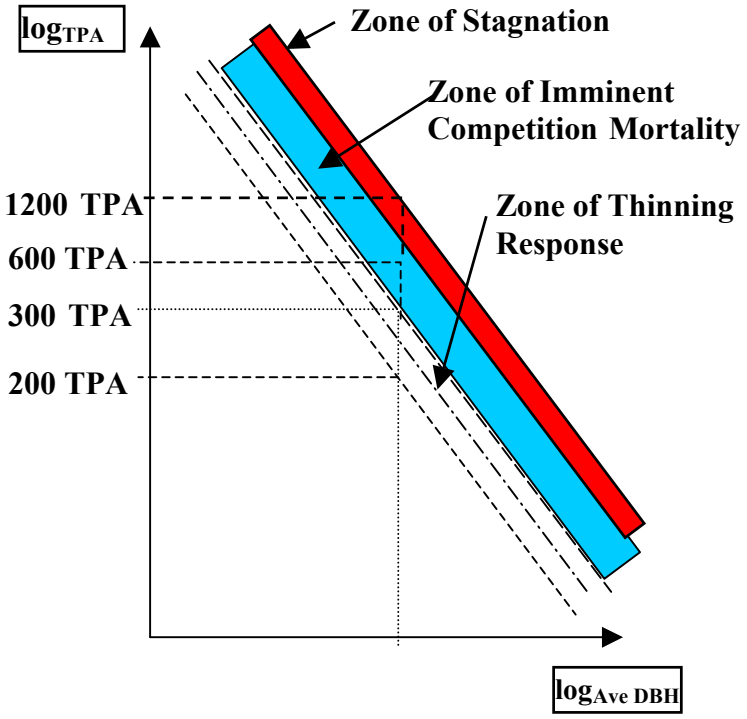
In modern society—with ten times the pre-Columbian human population, trans-global transmission of pathogens, and interruption of natural rejuvenating mechanisms such as fire, flood, and wind—these risks cannot be simply relegated to natural systems that societal pressures now pre-empt. Instead, the risks must be recognized and managed if social, economic, and environmental expectations of forested trust lands are to be realized. In summary, risk is present in both action and inaction. Thinning has a vital role in ameliorating risk on forested trust lands.

Traditional thinning—Thinning in the competitive exclusion stage

. . . how to measure competition . . .

First we will discuss how to measure competition within the competitive exclusion stage. Consider that, as tree seedlings grow, their individual spaces will eventually, and then increasingly, overlap. As trees grow and overlap increases, tree saplings begin to compete for the three resources trees must have to grow: light, nutrients, and moisture. Whichever of the three resources is least available will govern how competition expresses itself. In western Washington, light tends to be the most constrained of the three types of resources. Trees express this by shedding lower branches in order to maximize top growth and out-compete each other for light. (In eastern Washington, particularly in the ponderosa pine series, moisture is the most constraining factor, and

trees tend to express competition by spreading out in park-like stands as roots, not crowns, compete). Thus, as stands in the competitive exclusion stage grow, the number of trees per acre must eventually decrease. The graph below illustrates how several levels of competition—the diagonal lines—remain constant if trees per acre die as they grow in size, as measured by diameter at breast height (DBH). The graph shows that for an average DBH of 10 inches, an even-aged stand of a species with 200 trees per acre would be entering the zone of thinning response. At the same average DBH and 300 trees per acre the stand would verge on the zone of imminent competition-induced mortality. At over 600 trees per acre with the same average DBH, the stand would be entering a stagnation phase.



Note that the axes have logarithmic scales. Thus, otherwise curved lines become straight lines. The concept of expressing competition through an index DBH and trees per acre is called stand density index (SDI). Although data collection is labor-intensive, SDI illustrates competition in statistical terms.

Curtis' relative density, or RD

A similar, but more practical, concept for quantifying and measuring competition within a stand is Curtis' Relative Density (RD). This concept is the Department standard; data gathering and statistical manipulation are quick and easy. RD is also useable for mixed and uneven-aged stands if stands are judiciously stratified and the RD is stated as to which strata it applies. In the formula

$$RD = SBA \div \sqrt{QMD}$$

stand basal area (SBA), is the sum of the square footage of the cross-sections of all trees at breast height for an average acre. SBA is a simply measure of stocking. Quadratic mean diameter (QMD or D_g) is the diameter at breast height, in inches, of a tree with a basal area equal to the stand's arithmetic mean. The clear advantage of RD is the ease of a single person taking variable radius plots, while SDI requires fixed radius plots and a crew of two.

Regressions are universal; zones . . . are species-specific . .

RD can be graphed similarly to SDI, and the slope of SDI and RD regression lines will be the same, about –3/2. This is called "the rule of negative three halves." For RD, as for SDI, there are zones of thinning response, imminent mortality, and stagnation.

Slope of RD regressions are universal, regardless of species. However, the regressions that are associated with the zones of thinning response, imminent mortality, and stagnation are species-specific. One may think of this as related to the shade tolerance of each species; the further to the right these zones are, the more shade tolerant the species.

Traditional thinning should occur as a stand verges on the zone of imminent mortality . . .

Traditional thinning should occur as a stand verges on the zone of imminent mortality. This creates an optimal balance between natural pruning, forest health, and leave tree height growth, and is in fact the best way to imitate nature but without the delay caused by waiting for natural mortality to occur. When a tree species nears the zone of imminent mortality, crown ratios are over 30 and usually near 40 percent. In the zone of stagnation, crown ratios are less than 30 percent. With this knowledge, we can develop thinning guidelines for various species as follows:

	Douglas-fir, noble fir, or Sitka spruce predominance	**Western hemlock or true fir (other than noble fir) predominance**	**Mixtures**
Best to thin at:	55 ≤ RD ≤ 60	65 ≤ RD ≤ 70	RD of most shade tolerant species, +5
After thinning, there should be:	Crown Ratio ≥ 35% Height/diameter ratio ≤ 90 RD reduced by approximately 20 RD points but no more than 40% of pre-thinning RD (except when managing specific cohorts)		

. . . consider three kinds of thinning . . .

Now that we have discussed the relevant theory behind thinning in the competitive exclusion stage, let us view these thinnings from the perspective of how they are budgeted. This leaves us with three kinds of thinning: pre-commercial thinning (PCT), PCT with recovery rights (PCT-R), and commercial thinning (CT) in young stands. PCT is an unmitigated budget outlay since cut trees generate no revenue and, by being left on the ground, constitute an additional fire hazard (possibly leading to additional budget outlays). When cut trees are removed and sold to partly off-set cost (PCT with recovery rights), budgetary cost and fire hazard are minimized. If cut tree value exceeds logging and transportation costs—i.e., a CT—we incur both lay-out and compliance costs, but we also earn a modest income for the trusts as well as replenish management funds. If biologically feasible, it is therefore preferable to defer PCTs until the thinning can be sold as commercially valuable material.

"New Forestry" . . . Early entry to biodiversity pathways

Stands on other than GEM lands are thinned to enter and accelerate the pathway towards desired habitat while also enhancing growth. Thus, we thin both in and beyond the competitive exclusion stage. First, let's look at how the older stands we are trying to develop function.

Competition and response are somewhat different in stands that are beyond competitive exclusion from what we discussed above. Recall that trees in competitive exclusion stands compete for light in order to dominate space. In mature stands, however, there tends to be ample room between tree tops in the dominant and co-dominant canopy even though lower branches may touch. When niche-sized openings occur, sufficient light reaches the forest floor to generate a second canopy. Increasing numbers of larger snags develop cavities and eventually end up on the ground as large down woody debris (LDWD). As niches increase in complexity, there is a corresponding proliferation in floral, faunal, fungal, and microbial biodiversity. This causes nesting, roosting, and foraging (NRF) structure for northern spotted owls to eventually culminate in functionality.

Absent management of any kind, stochastic events will cause pathways through time that increase in biodiversity. Such pathways may take a millennium or less than a century. Thinning to accelerate biodiversity should therefore simulate stochastic events along pathways that rapidly generates biodiversity by creating fully functional stage as rapidly as possible. Thus, biodiversity thinnings enhance more than just growth of crop trees.

. . . "new forestry" . . . thinning to accelerate development of biodiversity pathways . . .

In traditional forestry, we were often taught that thinning had but one objective: to increase merchantable wood volume and thereby, profits. The scope, and perhaps understanding, was limited to stands in the competitive exclusion stage. "New forestry" thinning objectives are social and environmental as well as economic. Of particular focus in "new forestry" is thinning to accelerate development of biodiversity pathways in order to create habitat for critical species such as the northern spotted owl, the marbled murrelet, and riparian dependent species. "Critical species" refers to species that are health indicators for their particular ecosystem. Focusing on critical species implies securing sufficient habitat not only for a particular species but for all other species, known and unknown, that depend on the ecosystem's—as we superficially observe and define it—known and unknown nuances. The Department's Habitat Conservation Plan (HCP) for forested trust lands is intended to ensure that sufficient critical habitat for all known native species is developed and perpetuated. Since the plan is relatively recent, it stands to reason that critical habitat may be temporarily insufficient on a landscape basis. Thinning has a vital role in accelerating stand development to achieve habitat conditions as efficiently and effectively as possible. Furthermore, thinning for habitat and accelerating development of older forest characteristics, implies thinning to conditions beyond the competitive exclusion stage. In developing habitats for the northern spotted owl, we must not only accelerate the growth of individual trees, but also hasten development of niches and their functionality.

. . . "new forestry" . . . stresses variable stand density to emulate natural diversity . . .

In traditional forestry, we thin to uniform spacing, often in monocultures, to maximize wood volume and profits. New forestry recognizes synergistic benefits of mixing high-value shade-intolerant

and tolerant species (such as red alder and western redcedar or Douglas-fir and western redcedar) and stresses variable stand density that emulates natural diversity and resilience. Thus, even though we may model and prescribe for a single average density, on the ground density should vary by 5 to 7 RD points either side of the average. (This, by the way, is not unlike what we more-often-than-not ended up with when we tried to thin to perfect uniformity.)

As described in the HCP, A and B types of habitat for the northern spotted owl incorporate niches and openings, thickets, a lower canopy (shade-tolerant conifers plus hardwoods such as bigleaf or vine maple), snags or snag candidates, large down woody debris, and variable ground vegetation with frequent openings. What this describes is a forest on the verge of the "fully functional" stage. New forestry seeks to create these advanced stages and earliest possible habitat functionality.

Habitat objectives imply that variability be introduced as early as possible . . .

Habitat objectives imply that variability be introduced as early as possible and amplified as the stand ages. For example, oldest cohorts are left from the previous rotation. Shade tolerant and intolerant species are mixed when planting. Early thinnings increase diversity through leave tree selection, create small openings, leave small thickets, and enhance growth of dominants. Early CTs should begin to replenish snag and LDWD cohorts and, in the latter half of the first century, should nurture a second canopy and niche diversification while accelerating snag and LDWD replenishment.

The niche-related features that older stand thinnings strive to secure are (1) food for the prey (truffles growing on LDWD and seed from conifers and maples); (2) nesting opportunity for the prey—squirrels and voles—as well as for spotted owls (cavities in snags, trees, and LDWD); (3) "predator traps" i.e., openings in the ground vegetation where owls can successfully observe and pounce on their prey; (4) roosts and perches (lower canopy branches, particularly of suppressed trees and hardwoods) where owls rest/sleep and observe "predator traps", respectively; and (5) hiding and thermal cover provided by the dominant canopy and thickets. A baseline scale to consider over which variability may be imposed is on the order of ½ (¼ to 1) acre. Roughly 85 percent should be in two thinning densities (a spread of around 15 RD points) with the remaining 15 percent in skips and gaps. (Existence of other natural regional patterns should supersede this pattern.) This is called variable density thinning (VDT).

. . . VDT targets and manages multiple stand cohorts . . .

Unlike traditional forestry, VDT targets and manages multiple stand cohorts. Of course, in VDT we still nurture the crop, or commercial, cohort (were it not for the crop cohort, funds to manage other cohorts would disappear and DNR would have disregarded its trust mandate). However, VDT also provides for the roost (under-story), legacy, snag, LDWD, predator trap, thicket, and thicket recruitment (openings) cohort niches, and replacements may be recruited out of the crop cohort. The cartoon on the next page shows various cohorts after a VDT: (1) the dominant, mainly the crop, canopy in three densities—thicket (center), lower RD (right), higher RD (left); (2) snag (center); (3) LDWD (either side of the snag in center); (4) under-/mid-story hardwoods and conifers (left and right); (5) openings (landing with temporary log deck); (6) ground vegetation with cover and

"predator trap" openings (hemlock natural seedling patches and openings on forest floor); and (7) a harvested commercial cohort, here indicated by stumps and a log deck.

. . . at some point . . . the stand enters its habitat objective window . . .

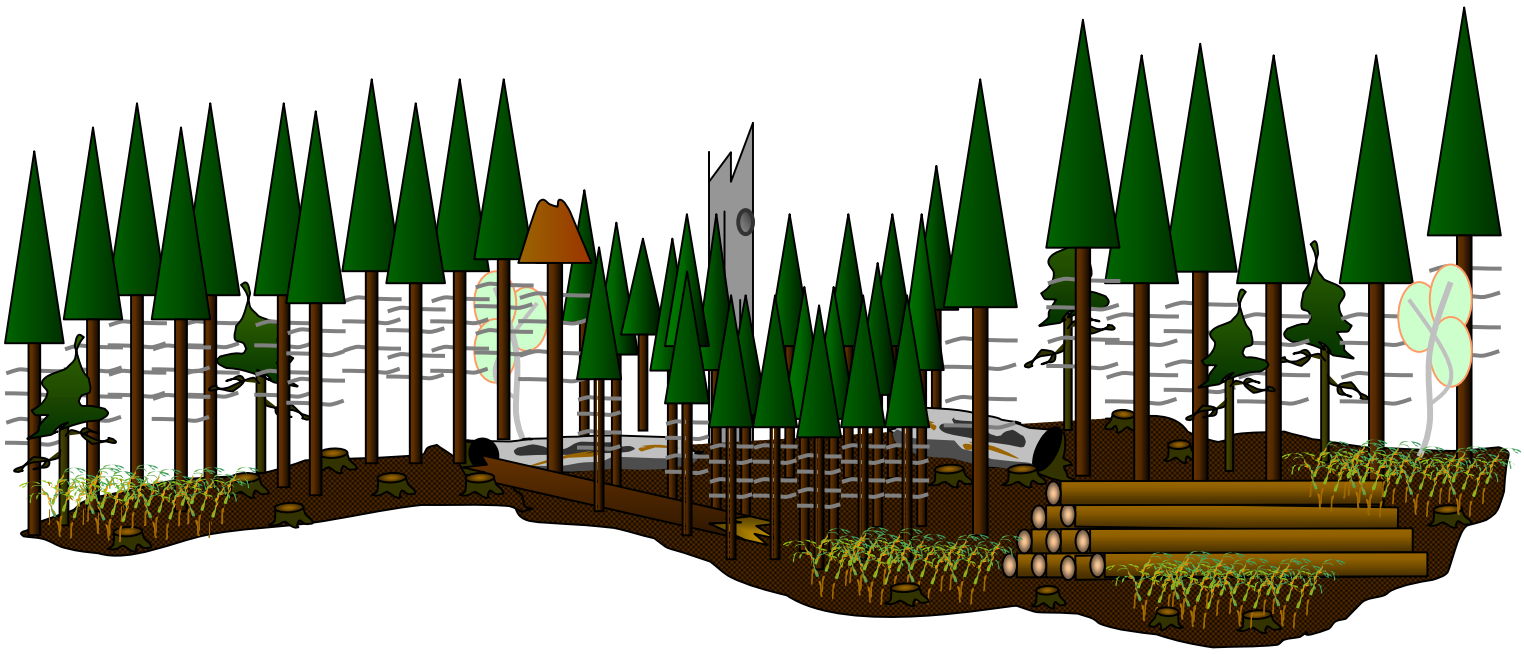
As stand development progresses, present cohorts gradually transform, often developing into other cohorts. The dominant canopy mostly becomes the future commercial cohort but may also contribute to replenishing the snag cohort; the snag cohort becomes the LDWD cohort, openings become thickets, and so forth. At some point, habitat threshold targets are all achieved. When this occurs, the habitat objective—such as *dispersal*, *sub-mature*, or *high quality nesting habitat*—is attained, and the stand enters a habitat FMU objective window. This is a pivotal occurrence in landscape management. A stand entering its habitat FMU objective window now contributes to the habitat landscape objectives and thereby frees up a corresponding acreage for harvest. Hence, forecasting this event in P & T makes availability of other stands for final harvest clearly visible to future foresters. This is how today's foresters communicate to future generations.

Techniques And Field Craft Of Thinning Decisions And Prescriptions

In discussing thinning techniques and field craft, we'll partly rely on illustrations such as cartoons and decision trees. We'll separate the discussion into three segments: (1) comparison of traditional thinning and VDT, (2) prioritization of candidate stands, and (3) translating silvicultural (rotational) prescriptions into activity prescriptions and activity prescriptions into marking/selection rules.

Comparison of traditional with variable density thinning

VDT has hidden economic opportunities. While variable density thinning (VDT) may seem overly



complex at first glance, the opposite may in fact be true. Let's look at the stand in the cartoon. You'll notice that, first of all, the "skip" around the old snag is required for safety reasons, and the opening around the landing would also be there in any kind of CT operation. You'll also notice understory trees are left and not felled, yarded, and piled for burning as was often the case in traditional thinnings. Furthermore, the stand to the left is denser than the stand to the right in the picture. Since the trees on the left are slightly smaller than the trees on the right, there is probably a constant basal area. However, since DBHs on the left are smaller, RD is higher than on the right. Such variability could serve to minimize risk of blowdown and would most likely have occurred whether the thinning was traditional or so-called variable density. In sum, variable density generally results even where we strive for uniformity; we simply need to accommodate the scale at which variability should exist, promote under-story development, replenish snags and LDWD, and create a few thickets and openings.

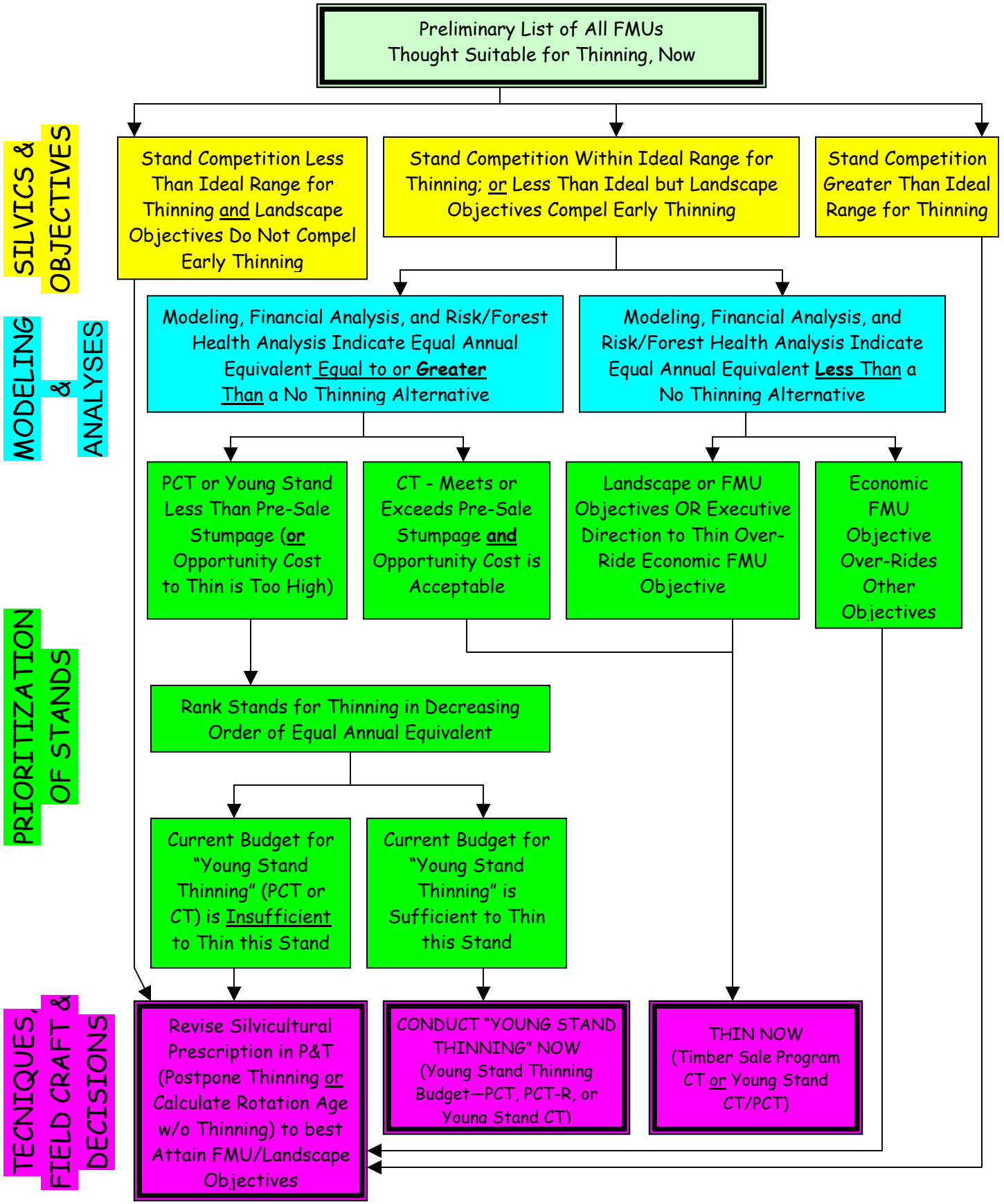
Thus, there are savings in not disposing of un-merchantable under-stories. There are also economic advantages to occasional openings—landings, decking and sorting areas, and converging skid roads—that are now essential (even though logging spurs and yarding corridors should still be at minimum width). Leaving the hard-to-reach areas and areas next to standing snags as un-thinned thickets is now mandatory according to forest practices regulations. However, it is crucial not to mistake a thinning that accomplishes variability only for a satisfactory VDT. Simple high grading accomplishes variability, but satisfactory VDT accomplishes variability while it also serves the trust mandate.

Prioritization of candidate thinning stands

Budgets for thinning are often uncertain. It is therefore important to have a rationale for prioritizing candidate thinnings as limited funds become available. Both management area and stand considerations bear on which stands should be thinned. For landscape reasons, stands capable of only modest economic returns may be selected for thinning over more productive stands. For example, thinning a modestly productive stand might bring a management area above minimal habitat criteria and thereby free up other stands for final harvest. Thinning this stand first would therefore be rational. In another case, low and high productivity thinnable stands might both equally contribute to landscape objectives. Then high productivity stands should be thinned first.

Modeling and financial analysis are useful tools to prioritize thinnings by forecasting greatest benefit to the trusts. The decision tree on the next page amplifies this logic and provides a comprehensive outline for comparing and prioritizing all candidate thinnings, at a point in time.

Prior to entering the decision tree, you should have produced a preliminary listing of stands that might currently benefit from a thinning treatment. Such a listing may simply be of all stands between 10 and 40 years of age that have not been thinned plus all stands that were thinned between 10 and 30 years ago and are not been designated for final harvest. In the future, once silvicultural prescriptions have caused all up-coming treatments to be scheduled, you will simply call for an extract from P&T.


Preliminary List of All FMUs Thought Suitable for Thinning, Now
SILVICS & OBJECTIVES
Stand Competition Less Than Ideal Range for Thinning and Landscape Objectives Do Not Compel Early Thinning
Stand Competition Within Ideal Range for Thinning; or Less Than Ideal but Landscape Objectives Compel Early Thinning
Stand Competition Greater Than Ideal Range for Thinning
MODELING & ANALYSES
Modeling, Financial Analysis, and Risk/Forest Health Analysis Indicate Equal Annual Equivalent Equal to or Greater Than a No Thinning Alternative
Modeling, Financial Analysis, and Risk/Forest Health Analysis Indicate Equal Annual Equivalent Less Than a No Thinning Alternative
PCT or Young Stand Less Than Pre-Sale Stumpage (or Opportunity Cost to Thin is Too High)
CT - Meets or Exceeds Pre-Sale Stumpage and Opportunity Cost is Acceptable
Landscape or FMU Objectives OR Executive Direction to Thin Over-Ride Economic FMU Objective
Economic FMU Objective Over-Rides Other Objectives
PRIORITIZATION OF STANDS
Rank Stands for Thinning in Decreasing Order of Equal Annual Equivalent
Current Budget for "Young Stand Thinning" (PCT or CT) is Insufficient to Thin this Stand
Current Budget for "Young Stand Thinning" is Sufficient to Thin this Stand
TECNIQUES, FIELD CRAFT & DECISIONS
Revise Silvicultural Prescription in P&T (Postpone Thinning or Calculate Rotation Age w/o Thinning) to best Attain FMU/Landscape Objectives
CONDUCT "YOUNG STAND THINNING" NOW (Young Stand Thinning Budget—PCT, PCT-R, or Young Stand CT)
THIN NOW (Timber Sale Program CT or Young Stand CT/PCT)

Translating silvicultural prescriptions into thinning activity prescriptions and selection rules

Translating silvicultural and thinning activity prescriptions into logger selection, or marking, rules is a vital action. This action must accurately reflect the overall rotational intent to attain FMU objectives along an optimal pathway.

Thus, the first step is to review FMU, or rotational, objectives for a annually generated preliminary list of stands scheduled for thinning. Universal FMU objectives are (1) maximize financial benefit consistent with other FMU objectives; (2) comply with laws, rules, policy (as reflected in higher order plans), and agency directives; and (3) a habitat objective that is either a specific habitat for a specific species or General Ecological Management (GEM).

The first objective consists of two threshold targets. The first of these is to maximize time value of money for the rotation henceforth, expressed as Equal Annual Equivalent (EAE) for intermediate entries. The second threshold target is to maximize positive current cash flow, expressed in current dollars. You also obtain stand tables that are statistically sound for modeling and financial analysis.

The second objective has one or more threshold targets for each law, rule, policy or directive to be implemented. For GEM lands, this objective is drawn from the Washington Administrative Code and covers habitat requirements.

The third – habitat – objective has threshold targets that are measurable and discrete. This objective is covered by laws, rules and regulations for gem Lands, but is separate for lands with specifically designated habitat, such as for the spotted owl.

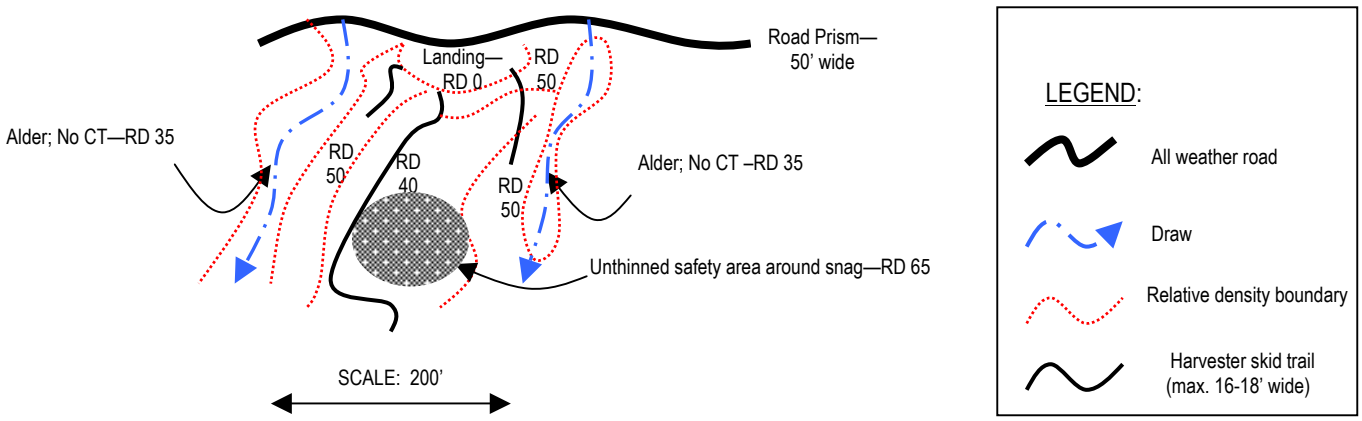
After completing this first step you are now at the first – gray – box in the decision tree on the previous page.

The next step is to determine feasibility for thinning. This often entails field visits to actually see and verify stand conditions as well to take plots for as modeling and financial analysis. The outcome of this analysis should be one of the following: (1) the stand has a relative density suitable for thinning, (2) the stand has yet to reach a RD suitable for thinning, or (3) the stand has degenerated past a condition suitable for thinning. This brings you through the yellow tier of the decision tree.

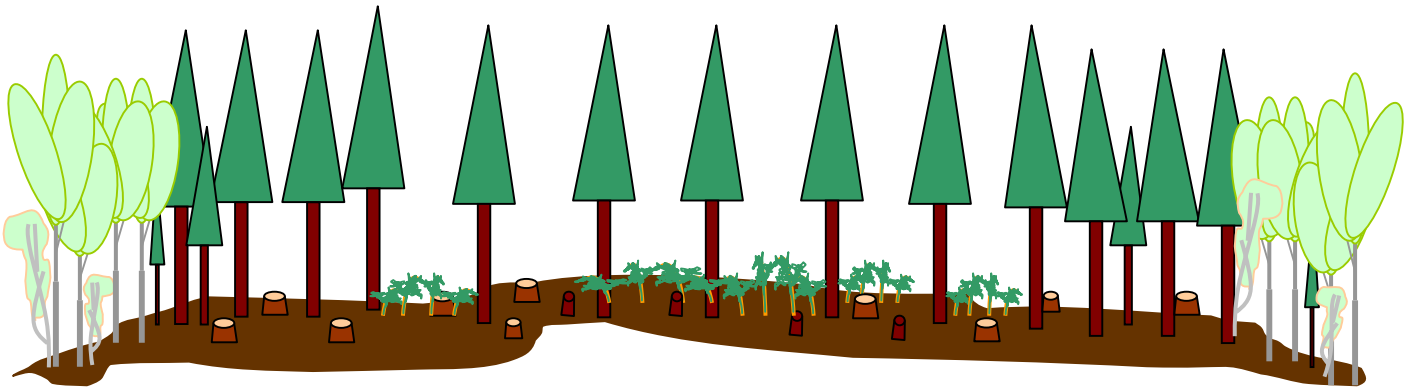
Following the decision tree through the blue (modeling and analysis) and green (prioritization) tiers, some stands will eventually receive a high priority for thinning – the two rightmost red boxes.

If you landed in the middle red box, young stand thinning only, you have a stand that is in the competitive exclusion stage. Here you are thinning to accelerate growth of the dominant canopy. In other words, you retain the largest and best trees, but you may also begin to introduce variability (species selection and RD variability, for example). To guard against risk (wind, snow) you leave an RD that is around 20 RD points less than the pre-thinning RD and generally remove no more than 40 percent of the pre-thinning RD. If you have an owl habitat objective, you should consider identifying and leaving end-of-rotation legacy trees in addition to other leave trees. You should

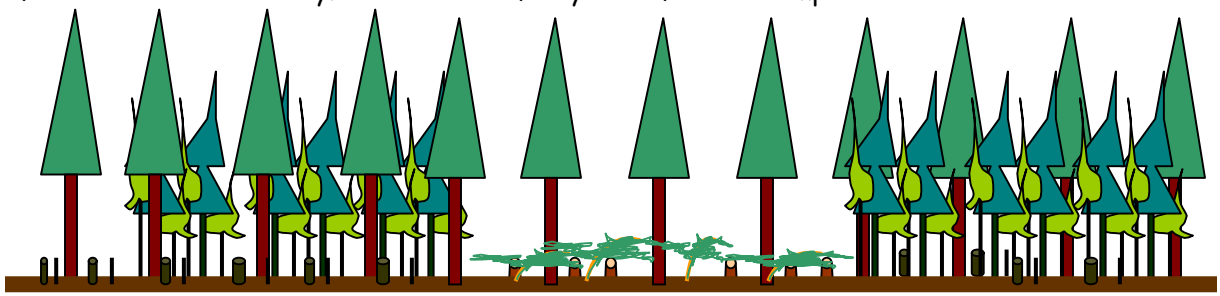
also begin to introduce variability into the stand. In introducing RD variability, follow land forms rather than an artificial pattern. Here is an example in a map view where RD variability follows side-ridges:



Taking this example as seen looking down the side-ridge it would appear as in the drawing below. A lower RD in the center of the side-ridge promotes development of a shade-tolerant understory while retaining existing species variability in the draws. After hemlock naturals—future roosts—seeded in, the stand would look like this:

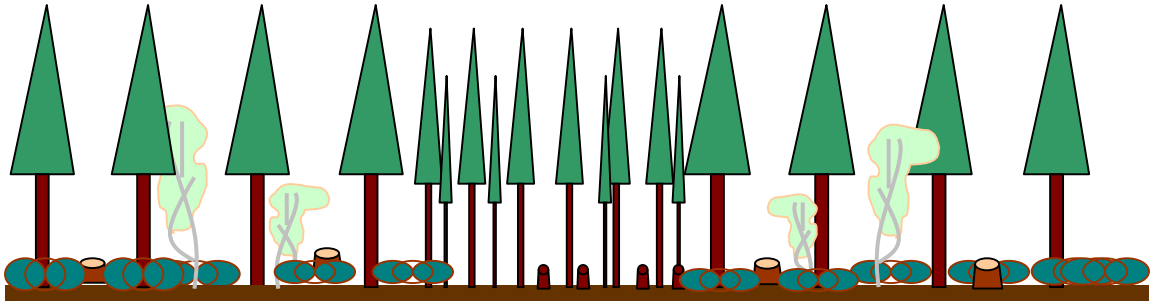


Another example, below, shows a stand with an existing shade tolerant or deciduous understory and a relatively open overstory. Here, thinning focuses on variable understory retention and minor modification to the overstory. A side-view a few years after CT completion would be:



In a third example, a stand with an inherent clumpy mix of intolerant and tolerant species, minimal understory and heavy salal ground vegetation, might best reach threshold targets by enhancing the variability already present. A technique is to mark for a single BA for the stand. However, if pre-

CT variability were short of targeted conditions, the emphasis should be shifted to prescribing a higher RD for tolerant than intolerant tree concentrations. Also, be cautious of heavy thinning; too much day-lighting may release the salal and not the leave trees. A post-CT side-view would be:



The collective message of these three examples[1] is that techniques and field craft are means to achieve activity objectives. The desired outcome is to mimic important mechanisms at work in aboriginal stands.

Specific techniques and field craft for thinning northern spotted owl habitat

In habitat for the northern spotted owl, HCP requirements supersede forest practice rules. Achieving maximum trust benefit must be in conjunction with attaining habitat threshold targets for stands and landscapes. The role of thinning, where allowed by the HCP, is to minimize the time it takes for stands for stands enter the habitat FMU objective window. Thus rotation lengths may become shorter than they might otherwise be, and this also synchronizes the highest possible timber volume and trust benefit over time with habitat imperatives. Older stand thinnings are used to further accelerate habitat quality improvement. Some techniques and field craft are:

- Apply variable density to ensure earliest possible attainment of habitat threshold targets (exclude unthinned and group selection areas from RD averages).
- Define the future commercial cohort(s), and use thinnings to maximize development towards high value product standards in this cohort.
- Define and identify cohorts are necessary for the spotted owl. Use thinning entries to replenish them so they are sufficiently sustained until the next projected entry and can in the next rotation further hasten entering the dispersal habitat condition window.
    - Sustain or create foraging habitat, particularly LDWD and "predator traps" (small openings in the ground vegetation where roosting owls may observe and strike their prey).
    - Retain snags and provide for recruitment from the largest tree class for nesting habitat (break out tops and excavate cavities as needed and practical).

[1] To avoid clutter, LDWD and snags/recruits, although vital for owl habitat, are not shown in these drawings.

- Unmanaged western hemlock and Pacific silver fir stands often fail to increase volume from CT because of blow-down and other sources of stand break-up following thinning. Therefore, these stands should be thinned only when risks are identified and sufficiently mitigated.

- *Thin from the middle* i.e., retain selected dominants / co-dominants (owl hiding and thermal cover), a component of mid / understory trees (roosting habitat), present and future snags (nesting habitat), and large down woody debris (LDWD) / recruits (prey base feeding habitat and "predator traps). The mid / understory will consist of deciduous tree species (two to three single stemmed bigleaf maple per acre, vine maple or alder) and / or shade tolerant suppressed or intermediate conifers.

- Spacing between leave tree crowns determines whether or not winds will get in between leave trees and cause blow-down or just sweep over the tops of them. The outer perimeter, or "dripline," of adjacent crowns should be used to estimate spacing. With some on-site experimentation, one can relate a desired dripline spacing to a targeted post-thinning stand basal area. Once you know the targeted post-thinning SBA, you can easily check you crew's or a logger's marking with a few variable radius plots.

- In the absence of landscape analysis to the contrary, use 80 and 140 years as baseline rotation lengths in dispersal and NRF management areas, respectively.

Specific techniques and field craft for thinning General Ecological Management (GEM) lands

GEM lands may forego thinning, specific habitat not being an objective. Beyond forest practices habitat rules, primary considerations on GEM lands are to benefit the trusts i.e., merchantable volume and value. The most common role for thinning on GEM lands is to adjust early stocking, maintain forest health and, if needed, to delay final harvest for selected stands for landscape management and even flow reasons. Thinning activity prescriptions and marking rules must therefore maximize value of merchantable volume by ensuring site occupancy with high-value trees at rotation's end. Some techniques and field craft are:

- Thinnings are treatments from which modest intermediate income is possible that are intended to maximize value of merchantable volume at rotation's end, and thinnings must not be over-done to increase current versus future benefit.

- Avoid opening the canopy to an extent that releases or generates unwanted understory or ground vegetation.

- Avoid opening the canopy in a way that is likely to cause heavy blow- or snow-down over the vulnerable post-thinning period—usually around a decade.

- Use trees designated to be harvested as "bumper trees" along skid/skyline roads to minimize damage to leave trees. Fell and yard bumper trees last for each road.

Residual damage to more than 5 percent of crop trees per acre is unacceptable.

- Consider economic benefits on stumpage of not felling and yarding sub-merchantable understory trees, or of forest health benefits resulting from stand diversity. (Note, that this is not true for the eastern Washington grand fir series in which forest health considerations mandate ensuring a minimal grand fir component.)

- Lower site quality stands ground should not be routinely CTed unless there is a demonstrable economic advantage and risk of prescription failure is duly mitigated. (Extended response times of low sites increase the risk of prescription failure through extended blowdown susceptibility, longer duration of post-treatment shock, and less stand vigor to combat pathogen introduction.)

- If the stand is generally pure WH or true fir (other than NF), notably overstocked, and older than 40 yrs, do not thin. Generally, such stands have poorly anchored root systems and low crown ratios. They are highly susceptible to blow-down.

- When CTing WH or TF dominated stands, keep dripline spacing $\leq$ 3'.

- Yard uphill as a rule. Skyline yarding with drop line carriage or yarding by shovel—or other long-reach (35 feet), low impact ground-based equipment—is preferred over highlead or tractor systems. Pre-yard to designated skyline corridors /yarding roads to limit leave tree and soil damage. Except whe deliberately creating openings, corridors/roads should be less than 18 feet wide and around 70 feet or more apart and preferably parallel (no "wagon wheels") to minimize soil compaction and confine it within less than average leave tree spacing. Hard-to-reach areas between skid trails should favor high densities, and vice versa.

APPENDIX A — Standard Forestry Terms

(Extract from: *Standard Forestry terms and Tree Names—A training and reference pamphletfor DNR management of forested trust lands—Draft 02-14-2006)*

Terms or definitions that are legally mandated will reference the source. Terms that are more general may not be cited as to their origins. Definitions cited as "(SAF)" originate from the Society of American Foresters' *Dictionary of Forestry* (1998).)

Activity In DNR's Planning and Tracking system, an undertaking in a FMU such as, various types of final harvest, reforestation, stand tending, or intermediate harvest (thinning).

Activity objective As pertains to DNR management of forested trust lands, the desired immediate, measurable, and, most likely, transient outcome of an activity. For example, the activity objective of a pre-commercial thinning might be to reduce stocking to 250 trees per acre, and the activity objective in reforesting a FMU might be to have 300 trees per acre in a vigorous 75:25 mix of Douglas-fir and western redcedar at the free-to-grow stage. (In both cases, the activity objective is most likely a transient condition on the pathway towards a rotation-end condition of a lesser number of trees per acre, to be achieved through subsequent plans.)

Activity prescription As pertains to management of forested trust lands, the prescribed outcome for the point in time at which an activity concludes.

Assessment As pertains to DNR management of forested trust lands, is a formal or informal examination of stand parameters that are relevant to the purpose at hand. Formal assessments consist of calibrated sample designs with plots, the data from which are analyzed statistically. Examples of formal assessments include stocking and survival surveys, timber cruises, PCT surveys, and FRIS exams; the common denominator is that data collection and use is based on a statistical parameters. Informal exams are usually so-called "walk-throughs," sometimes augmented with a plot here and there, but without deliberate statistical rigor. Synonyms—stand exam, stand assessment.

Basal area (BA) The cross sectional area of a single stem measured at breast height (SAF). For management of forested public lands, BA is generally expressed in square feet. Compare to stand basal area (SBA), a measure of stocking.

Basal area factor (BAF) The factor representing the basal area in square feet per acre applied to a variable radius plot. The number of "in" trees on a variable radius plot multiplied by the BAF equals the square feet per acre of stand basal area represented at that point.

Biodiversity pathways As pertains to DNR management of forested trust lands, an approach to achieving goals of biodiversity conservation which is "the management of human interactions with the variety of life forms and ecosystems so as to maximize the benefits they provide today and maintain their potential to meet future generations needs and aspirations" (Reid W.V. and K.R. Miller, 1989, Keeping options alive: the scientific basis for conserving biodiversity. World Resources Institute, Washington, D.C.). The term "biodiversity pathways" was popularized by Andy Carey, a USDA-Forest Service Pacific Northwest Research Station scientist in the Washington Forest

Landscape Management Project (Carey et al, 1996) as an approach that employs traditional silvicultural techniques and field craft and applies them to specific FMU objectives of biodiversity and habitat conservation while also incorporating revenue generation. The concept of biodiversity pathways conveys that forest stands evolve by events, or absence of events, and are otherwise constrained only by site productivity potential. Absent human influence, such events occur by chance; in managed stands they occur largely by design. For example, a given FMU objective, such as habitat for the northern spotted owl, may take anywhere from some decades to upwards of a millennium to develop along chance-driven natural pathways. Thus, how long a certain condition takes to materialize depends on site productivity (i.e., growth rate) and stochastic events. This spectrum of possible pathways ensues from circumstances associated with stand origin (fire, wind, seed-fall, species, etc.) and stand development (competition mortality, insects, disease, pre-European human intervention, etc.). The time required to attain functioning habitat may be reduced if developed and managed by design rather than by chance-driven, stochastic events. Biodiversity pathway and silvicultural regime concepts may thus be considered largely synonymous in their application and meaning. A silvicultural prescription is the optimal pathway (i.e., regime), within Nature's limits, to attain FMU objectives. A silvicultural prescription often employs accelerated means (planting, vegetation management, and thinning) to guide stand development along the desired pathway. (Variable density thinning—VDT—is a type of activity that accelerates biodiversity towards achieving spotted owl habitat.)

Biological diversity (biodiversity) As pertains to DNR management of forested trust lands, is the relative degree of abundance of living organisms considered at all levels of organization, including the genetic, species, and higher taxonomic levels, and the variety of habitats and ecosystems as well.

Blowdown A tree or trees felled or broken off by wind –*synonym* windfall, windthrow (SAF). [Ed. note—trees broken off by wind may be specifically referred to as "wind shear."]

Breast height (BH) A standard height from ground level, generally at 4.5 ft (1.37 m), for recording diameter, circumference (girth), or basal area of a tree (SAF). In DNR management of forested trust lands, BH is 4.5 feet above ground on the uphill side of the tree except for cases of fluting, pistol butt, or other basal deformity that extends 3.0 feet or more above the ground on the uphill side of the tree or in some cases of main stem forking. In the case of basal deformity of 3 or more feet, BH occurs 1.5 feet above the highest extent of the deformity. In the case of a tree that is forked at or below the "sighting point" (point at which the tree is determined in or out of a variable radius plot), the tree is considered as two separate stems and BH is 3.5 ft above the fork. However, a tree that is forked above the "sighting point" has its BH 4.5 feet above ground on the uphill side. See diameter at breast height (DBH).

Canopy As pertains to DNR management of forested trust lands, the continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody growth. A forest stand may have more than one distinct canopy.

Canopy closure As pertains to DNR management of forested trust lands, the proportion of the sky hemisphere that is obscured by vegetation when viewed from a single point. Canopy closure is

not precisely distinguished from canopy cover in DNR's HCP for forested trust lands. See also—crown closure.

Canopy cover As pertains to DNR management of forested trust lands, the proportion of the forest floor covered by the vertical projection of the tree crowns. Canopy cover is not precisely distinguished from canopy closure in DNR's HCP for forested trust lands. See also—crown closure.

Codominant A tree whose crown helps to form the general level of the main canopy in even-aged stands or, in uneven-aged stands, the main canopy of the tree's immediate neighbors, receiving full light from above and comparatively little from the sides (SAF).

Cohort As pertains to DNR management of forested trust lands, a term for forest stand components that are statistically distinct; generally, cohorts are identified when FMU objectives require them to be managed separately from other stand cohorts. For example, cohorts such as live wildlife reserve trees, snags, and LWD are statistically distinct because statutes, regulations, and DNR's HCP for forested trust lands require their management and retention beyond a single rotation. These trans-rotational, or legacy, cohorts co-exist with one or more rotational, commercial cohorts within the same FMU. While legacy cohorts are managed beyond single rotations to achieve environmental FMU objectives (such as wildlife and mycorrhizal habitats), one or more commercial cohorts within the same FMU are managed to achieve the economic FMU objective to generate revenue for the trusts on a rotational basis.

Commercial thinning (CT) As pertains to DNR management of forested trust lands, is thinning wherein the removed trees have merchantable value on the stump and are sold accordingly.

Conifer A cone-bearing tree –*note* the term often refers to gymnosperms in general (SAF). See also—softwood.

Crown The part of a tree or woody plant bearing live branches and foliage (SAF).

Crown class A category of tree based on its crown position relative to those of adjacent trees (SAF). [Ed. note—see codominant, dominant, emergent, intermediate, overtopped (suppressed), and predominant]

Crown closure For purposes of DNR management of forested trust lands, the stand development stage at which crown perimeters within a canopy extend laterally to where they touch.

Crown ratio the percentage of the stem that supports live green foliage (not counting epicormic branches and adjusting for uneven distribution of branches).

d/D ratio The ratio between quadratic mean diameters of a stand before and after thinning, respectively. Thus, a d/D ratio of 1 implies thinning throughout the diameter classes, a d/D ratio less than 1 implies thinning from below, and a d/D ratio greater than 1 implies thinning from above.

Decision tree A graphical representation of a sequential decision problem that facilitates analyses that explicitly incorporate the sequential nature of the decisions (SAF).

Deck An orderly stack of logs, usually located on or near a landing or along a forest road, that is often sorted by species and grade.

Department of Natural Resources (DNR) RCW 43.30.030 authorized creation of the department as consisting of a board of natural resources, an administrator, and a supervisor. A.k.a., Washington State Department of Natural Resources (WADNR). [Ed note—DNR was created in 1957 by the Legislature with the merger of numerous agencies, boards, and commissions into one professionally managed natural resource agency administered by a popularly elected commissioner of public lands.]

Diameter at breast height (DBH) The diameter of the stem of a tree as measured at breast height (SAF).

Diameter class DBH sorted into size classes, generally by 1 or 2-inch increments. For practical purposes, saplings and poles are generally divided into 1-inch diameter classes, while larger trees tend to be divided into 2-inch diameter classes. Seedlings do not have diameter classes as they, by definition, have yet to attain breast height.

Dispersal habitat As pertains to DNR management of forested trust lands and defined in DNR's HCP for forested trust lands, is habitat used by juvenile northern spotted owls or by owls of any age to disperse or move from one area designated for nesting-roosting-foraging habitat to another.

Eastside FMU threshold targets for dispersal habitat are:

- Canopy cover of at least 50 percent
- Overstory of at least 40 trees per acre of at least 11 inches DBH
- Top height of at least 60 feet
- At least four trees per acre from the largest diameter class designated for snag and cavity tree recruitment

Westside FMU threshold targets are:

- Canopy cover of at least 70 percent
- Quadratic mean diameter of at least 11 inches for the stand's largest trees
- Top height of at least 85 feet
- At least four trees per acre from the largest size class designated for snag and cavity tree recruitment

Dispersal management area As pertains to DNR management of forested trust lands and defined in DNR's HCP for forested trust lands, a SOMU that will be managed so that dispersal habitat (or better) for the northern spotted owl is perpetuated over at least 50 percent of the management area.

DNR's HCP for forested trust lands A HCP that applies to DNR management of specified forested trust lands to assure long term protection and benefit of endangered species within defined areas. The HCP was signed in 1996 in agreement with the U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration - Fisheries Service. The plan covers

approximately 1.6 million acres of forested trust lands within the range of the northern spotted owl.

Dominant *A tree whose crown extends above the general level of the main canopy of even-aged stands or, in uneven-aged stands, above the crowns of the tree's immediate neighbors, receiving full light from above and partial light from the sides (SAF).*

Down Woody Debris—*see LWD.*

Dripline The outside perimeter of the crown of a tree; dripline spacing is the distance between driplines of adjacent trees, a measure useful in regulating air movement between trees and therefore for avoiding blowdown.

Emergent *A tree whose crown is completely above the general level of the main canopy, receiving full light from above and from all sides (SAF).*

Equal annual equivalent (EAE) *A financial analysis parameter that represents an infinite succession of discounted annual payments to the landowner and is based on net costs and revenues from either whole or partial rotations. Unlike BLV (which can only be used for whole rotations), EAE can be used to equitably compare discounted values of various intermediate treatments.* [2]

Final harvest *As pertains to DNR management of forested trust lands, the harvest that signifies the end of a rotation by harvesting all available trees within a FMU. (Forest practice regulations (Title 222 WAC) requires retention of multi-rotational cohorts when final harvesting commercial cohorts. The multi-rotational cohort(s) may be augmented beyond forest practice requirements if mandated by FMU objectives.)*

Financial analysis *A process that quantifies the financial investment value of a silvicultural regime. Financial analysis is intrinsic to DNR silvicultural prescriptions, because trust lands have a legal mandate to maintain undivided loyalty to the trusts, manage trust lands in the interests of the beneficiaries, and to make trust properties generate revenue without unduly favoring present beneficiaries over future beneficiaries. Time Value of Money (TVM) calculations such as Net Present Value (NPV)*[3] *are useful in comparing regimes of equal rotation lengths in terms of return on capital invested. To equitably compare rotations of unequal duration, a refined form of NPV, Bare Land Value (BLV)*[4]*, is a more equitable tool. To accomplish equitable comparison of thinning entries,*

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[2] Calculated through the formula EAE = NPV * $\{i * (1 + i)^n \div [(1 + i)^n - 1]\}$, wherein "NPV" is the regime's present net worth, "i" is the discount rate, and "n" is the number of years (compounding periods) in the regime.

[3] Present value, PV, is computed through the formula $PV = V \div (1 + i)^n$, wherein "V" is the value, positive or negative, at the time of occurrence in real (i.e., un-inflated) dollars, "i" is the discount rate, and "n" is the number of discounting periods—years, in this case—from present. Net present value is the net of all PVs for a regime: $NPV = \Sigma_{PV}$.

[4] $BLV = NFV \div [(1 + i)^n - 1]$, wherein "NFV" is net future value i.e., the net of all real value revenues, positive as well as negative, each compounded until the end of the rotation (expressed mathematically, $NFV = \Sigma_{FV}$ wherein

where the stand is entered during the course of the rotation, Equal Annual Equivalent (EAE)[5] is a commonly used parameter. The department presently uses a standard discount rate of 5 percent per year and an appreciation rate of 1 percent per year for timber values and costs. All rates and values are in real terms i.e., with inflation subtracted.

FMU objective As pertains to DNR management of forested trust lands, a defined and measurable future state that a FMU must attain within the present rotation. FMU objectives fall into social, economic, or ecological categories. They emanate directly from law, policy, executive directives, public concerns, financial and market considerations, landscape objectives, and biophysical constraints. A FMU objective consists of an action verb and a brief descriptor/label, plus, sometimes, a modifier. Examples are: "attain sub-mature NRF;" "maximize BLV, consistent with other FMU objectives;" and "maintain hiking trail 'X' in a useable condition at all times except during FMU management activities." The first example is an ecological FMU objective, the second an economic FMU objective with a modifier ("consistent with other FMU objectives"), and the third a social FMU objective, also with a modifier.

FMU objective window As pertains to DNR management of forested trust lands, the period during which a managed stand meets the particular FMU objective i.e., all threshold targets that make up the FMU objective are fully satisfied. For instance, a FMU with an ecological objective to "attain NRF" enters the FMU objective window when the last threshold target to be met is attained. For example, a silvicultural prescription for a relatively high site class FMU in the grand fir series in the Klickitat HCP planning unit may indicate the objective window for sub-mature NRF being entered at age 45 and exited at final harvest, age 110.

Forest An ecosystem characterized by more or less dense and extensive tree cover, often consisting of stands varying in characteristics such as species composition, structure, age class, and associated processes, and commonly including meadows, streams, fish, and wildlife (SAF).

Forest health Defined in RCW 76.06.020 as "the condition of a forest being sound in ecological function, sustainable, resilient, and resistant to insects, diseases, fire, and other disturbance, and having the capacity to meet landowner objectives." The act also specifies overstocking as a primary indicator of forest health being imperiled.

Forest management unit (FMU) As pertains to DNR management of forested trust lands, a forest area designated for management to produce a future stand and attain a specific set of FMU objectives that are consistent with DNR policy. The boundary of a FMU is determined by a variety of factors such as operability limitations as well as bio-physical factors that collectively constitute attributes expressed as forest stands. At the time a FMU is defined, it may be a part or all of an existing FRIS sample unit (FIU), or it may contain parts of several existing FIUs so long as the ecological conditions are sufficiently similar to attain the FMU's objectives at essentially the same

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$FV=1/(1+i)^n$); "i" is the compounding/discounting rate; and "n" is the number of years—compounding periods—in the investment period (i.e., rotation).

[5] See footnote 2, above.

time throughout the FMU. A FMU is generally identical with the new stand and is the unit of land for which the final silvicultural prescription is developed.

Forest practice As defined in RCW 76.09.020, is any activity conducted on or directly pertaining to forest land and related to growing, harvesting, or processing timber, including but not limited to:

(a) Road and trail construction
(b) Harvesting, final and intermediate
(c) Pre-commercial thinning
(d) Reforestation
(e) Fertilization
(f) Prevention and suppression of diseases and insects
(g) Salvage of trees; and
(h) Brush control

"Forest practice" shall not include preparatory work such as tree marking, surveying and road flagging, and removal and harvesting of incidental vegetation from forest lands such as berries, ferns, greenery, mistletoe, herbs, mushrooms, and other products which cannot normally be expected to result in damage to forest soils, timber, or public resources.

Forest resource inventory system (FRIS) As pertains to DNR management of forested trust lands, a centrally managed inventory of the Department's forests that is based on scientific sampling. The inventory is delineated into forest inventory units (FIUs) defined by aspect, topography, elevation and homogeneity of tree canopy cover. Collected information is stored by stand attribute averages as a data layer in GIS.

Forestry The profession embracing the science, art, and practice of creating, managing, using, and conserving forests and associated resources for human benefit and in a sustainable manner to meet desired goals, needs, and values (SAF).

Forest vegetation simulator (FVS) A USDA-Forest Service sponsored and maintained forest stand growth, yield, and mortality simulator. FVS has specific model variants for different geographic locations. There are also extensions that attempt to quantify impacts of disturbance events such as insect or disease conditions or fire. For purposes of forested trust lands management, FVS is considered more suitable for eastern than western Washington forests.

Form class—see Girard form class.

General ecological management (GEM) A as pertains to DNR management of forested trust lands, the label for lands for which there are general i.e., no species-particular, requirements for wildlife habitat.

Girard form class As pertains to DNR management of forested trust lands, is the ratio between DIB at the top of the first log and DOB at BH. Often called simply form class.

Growth and yield table A table showing the expected timber yields by age of an even-aged stand, usually by site class, and typically including quadratic mean diameter or mean DBH, height, number

of stems, basal area, and standing volume per unit area; yield tables may also include volume of thinnings, CAI, MAI. . . and other data (SAF). See also—stand simulator.

Habitat 1. a unit area of environment 2. the place, natural or otherwise, (including climate, food, cover, and water) where an animal, plant, or population naturally or normally lives and develops (SAF).

Habitat conservation plan (HCP) A plan authorized under section 10 of the federal Endangered Species Act that delegates to the U. S. Secretary of Interior to permit incidental take from an otherwise lawful activity of a species protected under the Act. To be approved by the Secretary, a HCP must provide for mitigation of impacts expected to ensue from planned activities and must also guarantee funding accordingly. DNR has a HCP for forested trust lands signed in 1996 in agreement with the U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration - Fisheries Service acting as agents for the Secretary. DNR also expects approval in 2006 of a HCP for forest practices regulations that will apply to both private and public lands within the state of Washington.

Hardwood Trees belonging to the order Angiospermae. 2. the xylem of Angiospermae (SAF). Compare to—softwood.

Height-diameter ratio (h/D ratio) For purposes of DNR management of forested trust lands, the ratio of total tree height divided by DBH, both measured in feet.

Intensive management As pertains to DNR management of forested trust lands, planned and pro-active progression of forest stands or FMUs along deliberate pathways in which activities are steps that advance attainment of rotational FMU objectives.

Intermediate (referring to crown class) A tree whose crown extends into the lower portion of the main canopy of even-aged stands or, in uneven-aged stands, into the lower portion of the canopy formed by the tree's immediate neighbors, but shorter in height than the codominants and receiving little light from above and none from the sides (SAF).

Intermediate harvest A timber harvest performed separate from, and prior to, final harvest.

Intermediate treatment A category of intra-rotational silvicultural treatments/activities that includes tending and intermediate harvests such as commercial thinning.

Landing A widened area (often on or adjacent to a forest road) to which logs are yarded or skidded for loading onto trucks to be hauled to market. *Note* – a swing landing is located away from forest roads.

Landscape As pertains to DNR management of forested trust lands, a generally cohesive group of stands or FMUs that make up a planning area under DNR's HCP for forested trust lands. In a general sense, landscapes and landscape-sized areas are determined at a scale governed by specific

issues. Such issues include productive habitat for individual species of wildlife, scenic considerations, and industry and community perpetuation.

Landscape objective See—management area objective.

Large woody debris (LWD) As pertains to DNR management of forested trust lands and defined in DNR's HCP for forested trust lands, large pieces of wood in stream channels or on the ground – includes logs, pieces of logs, and large chunks of wood; provides streambed stability and/or habitat complexity. Also called coarse woody debris (CWD) or large down woody debris (LDWD).

Management area As pertains to DNR management of forested trust lands, a generally sub-landscape defined by a single issue such as habitat for the northern spotted owl, visual objectives, or timber production.

Management area objective As pertains to DNR management of forested trust lands, a management area objective characterized by managing to attain, and then sustain, a specified proportion of the management area in a particular FMU objective window for the life of the objective.

Management area strategy As pertains to DNR management of forested trust lands, a 10-year schedule of activity types and associated outputs (such as a harvest schedule with associated harvest volumes) for a specified administrative management area that meet the DNR policies, procedures and local constraints. Regions determine these administrative landscapes (for example P&T Admin_Unit, Landscape, District, Unit, etc.).

Mature *of trees or stands* pertaining to a tree or even-aged stand that is capable of sexual reproduction (other than precocious reproduction), has attained most of its potential height growth, or has reached merchantability standards—*note* within uneven-aged stands, individual trees may become mature, but the stand itself consists of trees of diverse ages and stages of development (SAF) – See also, mature stand and overmature, as both are defined in DNR's HCP for forested trust lands.

Mature stand As pertains to DNR management of forested trust lands and defined in DNR's HCP for forested trust lands, the period of a forest stand's life that begins with culmination of mean annual increment and ends at the old-growth stage or at 200 years. This is a time of gradually increasing stand diversity. Hiding cover, thermal cover, and some forage may be present. See also—overmature, which in the Society of American Foresters' Dictionary of Forestry has a meaning similar to the meaning of "mature" in the HCP.

Mean annual increment (MAI) The total increment [ed. note—as measured in volume per acre, QMD, or mean height] of a tree or stand (standing crop plus thinnings) up to a given age divided by that age (SAF). [Ed. note—USDA-Forest Service defines rotation length for a stand as culmination of MAI which, in turn, is defined as the age where MAI equals periodic annual increment (PAI)].

Nesting, roosting, and foraging habitat (NRF) As pertains to DNR management of forested trust lands and defined in DNR's HCP for forested trust lands, is habitat with the forest structure, sufficient area, and adequate food source to meet the needs of a nesting pair of spotted owls. The forest structure consists of stands at least 70 years old that include a three-layer canopy of very large diameter trees (200+ years old) from the previous stand, large diameter trees (70+ years old), and small understory trees, along with snags and large down woody debris.

NRF management area A land area identified in DNR's HCP for forested trust lands that will be managed to provide to attain sub-mature habitat conditions and thereby provide demographic support, and contribute to maintaining species distribution for the northern spotted owl.

Objective As pertains to DNR management of forested trust lands, a desired future forest state that is defined through discrete measurable parameters (threshold targets). Objectives exist for activities, FMUs, and management areas. Note—a desired future state that is incompletely defined in terms of discrete measurable parameters is termed a desired future/forest condition or DFFC.

Overmature 1. a tree or even-aged stand that has reached that stage of development when it is declining in vigor and health and reaching the end of its natural life span 2. a tree or even-aged stand that has begun to lessen in commercial value because of size, age, decay, or other factors (SAF). See also—mature stand, a definition in DNR's HCP for forested trust lands in which "mature" has a meaning similar to SAF's definition of "overmature."

Overstocked As pertains to DNR management of forested trust lands in general, is a stocking level at which a stand will encounter mortality due to suppression or, pertaining to managed stands specifically, is a stocking level that exceeds the prescribed level for any given stage of stand development. See also—forest health.

Overstory (a.k.a., upper canopy) As pertains to DNR management of forested trust lands, the upper canopy in a multi-canopy stand.

Overtopped (suppressed) (a crown class) A tree whose crown is completely overtopped by the crowns of one or more neighboring trees –*note* the vigor of overtopped (suppressed) trees varies from high to low depending on individual circumstances (SAF).

Partial cutting As pertains to DNR management of forested trust lands, a USDA-Forest Service originated term for timber harvest activity that is set apart from clearcutting and is usually quantified in percentage of basal area removed. The term is insufficiently precise for most DNR silvicultural prescription purposes. In 2004, however, DNR used this tem in the Sustainable Harvest Calculation (SHC) to describe a spectrum of harvest activities between regeneration harvests (in which a minimum of 8 trees per acre are retained) and traditional commercial thinnings (in which generally around 30 percent of the stand basal area is removed uniformly from across the stand). In the SHC preferred alternative, "partial cut" was simply a convenient term to represent an array of heavy thinnings as biodiversity pathways promoting harvest activities. The intent was to enable the field forester to determine and designate which cohorts to remove and leave

depending on the rotational purpose for the activity. The field forester would subsequently precisely name the type of activity. Terms that precisely define the activity and its purpose include thinning, variable retention harvest, variable density thinning, and selective cutting; cohort management would be the associated silvicultural system.

Pathway a sequence of stochastic or managed events that interspersed between intervals of non-events, that collectively generate a specific condition at a point in time. Used in the term biodiversity pathways. In managed forestry scenarios, pathways are similar to a regimes.

Periodic annual increment (PAI) The growth of a tree or stand observed over specific time period divided by the length of the period –*see* mean annual increment (MAI), current annual increment (CAI), periodic increment (SAF).

Periodic increment The growth of a tree or stand over any specified period, commonly 10 or 20 years –*see* mean annual increment, periodic annual increment (SAF).

Planning and Tracking (P&T) The DNR's proprietary computer-based and GIS-linked activity inventory and scheduling system in which silvicultural prescriptions and activity accomplishments are recorded and accessed by FMU. P&T is the DNR's "corporate memory" for silvicultural activities.

Planning unit As pertains to DNR management of forested trust lands and defined in DNR's HCP for forested trust lands, are DNR-managed land units, grouped into three blocks for the purpose of implementing the HCP: the Olympic Experimental State Forest, five west-side planning units, and three east-side planning units. More specifically, these nine planning units in the HCP are: Olympic Experimental State Forest, South Coast, North Coast, Columbia, Straits, South Puget, Chelan, Yakima, and Klickitat.

Planting A step in artificial reforestation wherein forest tree seedlings are individually handled and placed in the ground in accordance with strict specifications.

Pole 1. a tree of a size larger than a sapling [ed. note—in the Pacific Northwest, poles are trees between 4.5 and 8.0 inches DBH] and smaller than a mature tree (SAF), and 2. for purposes of DNR timber sales, a log scaling grade that signifies a Douglas-fir or western redcedar log with approximate dimensions of at least 35 feet from the stump cut to a 6 inch top diameter measured outside the bark, line-straight, no more than 1 inch of sapwood, a Girard form class of .65 to .80, and a minimum DBH of 12 inches.

Pre-commercial thinning (PCT) As pertains to DNR management of forested trust lands, is thinning wherein felled trees have negative stumpage (usually because of insufficient size) and are therefore left where felled.

Pre-commercial thinning with recovery rights (PCT-R) As pertains to DNR management of forested trust lands, PCT wherein per acre cost is reduced by allowing the contractor to recover and sell thinned trees that have negative stumpage but positive pond value.

Predominant (a crown class) A tree whose crown has grown above the general level of the upper canopy (SAF).

Prescription As pertains to DNR management of forested trust lands, is an activity or a sequence of activities to attain threshold targets that in aggregate represent desired conditions in forests, or parts of forests. Prescriptions exist at two scales and are directed towards three time horizons. First, at the FMU scale, activity prescriptions mean to attain activity objectives in the near-present, while silvicultural prescriptions mean to attain FMU objectives within rotations. Second, at the landscape scale, landscape prescriptions tend to be activities for FMUs in the landscape, scheduled over space and time, that in aggregate attain a specified condition for a portion of the landscape (i.e., attain landscape objectives) and then sustain this proportion of a given stand condition over the landscape indefinitely.

Quadratic mean diameter (QMD or D_q) The diameter corresponding to mean basal area (SAF). For DNR forestry this means the DBH of a stand's theoretical tree of mean basal area. QMD is calculated by first dividing trees per acre into stand basal area and then using this mean tree basal area (BA) to calculate the radius through the formula QMD = $2 \times \sqrt{(\Pi \div BA)}$.

Regime As pertains to DNR management of forested trust lands, a timed sequence of specified FMU entries, and absence of entries, construed to attain and sustain a FMU's objectives. (A silvicultural prescription is the regime that best attains a FMU's objectives.) The term "regime" may also be synonymous with the newer term "biodiversity pathway" while the term silvicultural system may mean a generalized regime.

Relative density (RD) A mathematically derived parameter that indicates the level of intra-stand competition between trees, and consequently, a theoretical optimal range for thinning. RD guidelines for thinning vary by species and sometimes other factors, such as climatic zones. The commonly used version of RD is formally known as Curtis' RD after Bob Curtis, USDA-Forest Service biometrician who developed the measure. In the formula $RD=BA \div \sqrt{D_q}$, RD is Curtis' RD, BA is basal area per acre in square feet, and D_q is the diameter in inches of a tree of average SBA (i.e., quadratic mean diameter). Cutis' RD correlates to other measures of intra-stand competition, such as stand density index (SDI) and spacing – top height ratio (STH). RD is preferred over SDI because of ease of data collection and over STH in commercial stands for the same reason; STH, however, may be preferred in younger stands where branches block the view of tree stems from plot center.

Risk Combined probabilities of failure and extent of failure. Risk may be assessed for all projects to avoid or mitigate unacceptable risk factors, thus increasing the probability of success as close to certainty as feasible. Assessing risk consists of three steps: identifying risks factors, assigning probabilities of occurrence and extent and multiplying the two for a combined risk factor, and thirdly, determining whether or not the risk factor is acceptable. For example, imagine a proposed thinning in 50-year old second growth natural western hemlock stand with a RD of 90. Post-thinning blowdown is judged as an elevated risk factor until the stand again grows into crown closure, estimated to occur 10 years hence. Based on experience, the probability that cumulatively 80

percent of the residual stand will blow down in the next 10 years is estimated as 90 percent. Thus, the blowdown risk factor is .9 x .8 = 72 percent, which can be interpreted as 72 percent of the volume and value of the stand is likely to be compromised. Meanwhile, the estimated volume/value-gain from a fully successful thinning is 15 percent. For risk induced by this thinning to be acceptable, it should be less than 15 percent, say 5 or 10 percent. Thus, in this particular case one would conclude that risk induced by thinning is so far from an acceptable level that it cannot be sufficiently mitigated, and the risk is therefore unacceptable. Viable options for this fictional stand would therefore not include thinning.

Rotation In even-aged systems, the period in years between stand initiation and final harvest. As pertains to management of forested trust lands in particular, rotation has two specific meanings. On the one hand, rotation denotes the FMU age at which, from a landscape and financial analysis standpoint, final harvest is scheduled to occur. On the other hand, from the stand point of execution, rotation denotes the FMU age at which final harvest actually occurs.

Salvage Logging (over and above what is programmed in harvest schedules) performed to sell blowdown, insect infested, or otherwise damaged timber before natural processes cause deterioration in quality and value.

Sapling A usually young tree larger than a seedling [ed note—in the Pacific Northwest, a tree seedling has a stem less than 4.5 feet in height i.e., it has no DBH] but smaller than a pole (SAF) [ed. note—poles, in this context, are between 4.5 inches and 8.0 inches DBH].

Sawlog A log that meets minimum regional [ed. note—pertains to U. S. region] standards of diameter, length, and defect, intended for sawing [into dimensional lumber] (SAF). See also timber and note that DNR's GIS has separate classifications for small and large sawtimber.

Seedling For purposes of DNR management of forested trust lands, defined as a juvenile tree, naturally or artificially germinated, whose stem is no more than 4.5 feet in height and therefore has no DBH. Note 1— trees younger than 1 year of age are generally called germinants or "buttons"; Note 2.—after reaching 4.5 feet in height, the tree has a DBH and is considered a sapling); Note 3—forest nursery crops consist of cultivated seedlings that are out-planted in FMUs where they grow until they have fulfilled the FMU objective.

Selective cutting As pertains to DNR management of forested trust lands, an uneven-aged silvicultural system as well as a term for associated intermediate harvests. In selective cutting, harvests may depend on specific market criteria that involve strict grade requirements. Selective cutting may be motivated by objectives other than financial investment, such as scenic values or a cash flow response to a temporary market niche.

Shelterwood (a final harvest system) The cutting of most trees, leaving those needed to produce sufficient shade to produce a new age class in a moderated microenvironment—*note* the sequence of treatments can include three types of cuttings: (a) an optional preparatory cut to enhance conditions for seed production; (b) an establishment cut to prepare the seed bed and to create the new age class; and (c) a removal cut to release established regeneration from competition with the

overwood; cutting may be done uniformly throughout the stand (uniform shelterwood), in groups or patches (group shelterwood), or in strips (strip shelterwood); in a strip shelterwood, regeneration cutting may progress against the prevailing wind (SAF). [Ed. note—for DNR trust forest land management, group or strip shelterwood is somewhat common, particularly for higher sites in the ponderosa pine series, where shapes and orientation of openings are geared to balancing the need of seedlings for direct sunlight with their need for protection against sunscald and desiccation].

Silvics The study of the life history and the general characteristics of forest trees and stands, with particular reference to environmental factors, as a basis for the practice of silviculture (SAF).

Silviculture For purposes of DNR management of forested public lands, is the art and science of cultivating forests to achieve objectives. (This concept incorporates theory, planning, and practice at the stand through landscape scales.)

Silvicultural prescription For purposes of DNR management of forested trust lands, the optimal regime selected to attain FMU objectives.

Silvicultural system A planned series of treatments for tending, harvesting, and re-establishing a stand (SAF). For purposes of DNR management of forested trust lands, a silvicultural system is signified by a term that represents a generalized regime of a forest stand from the present until attainment of an envisioned future state (at or prior to final harvest). In classical forestry, silvicultural systems are divided into two main categories: uneven-aged and several even-aged systems. Classical even-aged silvicultural systems include clearcut, seed tree, and shelterwood (these are also termed final harvest systems and then only refer to the treatment at final harvest). The DNR's trust mandate combined with environmental and social objectives generate practices that depart from these theoretical and idealistically pure systems. In actual practice, the DNR often employs cohort management, wherein various FMU cohorts are managed for diverse FMU objectives over different time spans; because of the DNR's founding principles, there is always at least one prominent commercial cohort that is frequently grown in even-aged concentrations exposed to direct sunlight.

Site As pertains to DNR management of forested trust lands, is a specific forest locale that, in some discernible way is distinct from its surroundings, such as a FMU.

Site class A grouping of site indices. Generally in the state of Washington, Douglas-fir site index using a 50-year base, are grouped into site classes as follows:

Site Class	Site Index Coverage	Inter-Nodal Growth Rule-of-Thumb for Douglas-fir
I	136 and higher	≥ 4 feet
II	116 - 135	3 feet
III	96 - 115	2 feet
IV	76 - 95	1 foot
V	75 and lower	< 1 foot

The inter-nodal growth column represents a rule-of-thumb for quick field assessments. It should be applied between the free-to-grow and growth retardation stages. Retardation stages may occur both late and early in a stand's life span, and are usually correlated with geographic location for specific areas. Such variations, although often significant, are outside the scope of published site class determinations. For example, dry-land stands tend to have several years of slow growth before tree roots reach sufficient soil moisture required for maximum height growth for the site. Likewise, dry-land stands tend to also exhibit sudden growth retardation when roots reach unfavorable soil conditions, such as the coarse and unfertile C-horizon, bedrock, or roots of adjacent trees. Slow growth stages have profound implications for management. First, one might consider ripping furrows in which to plant trees in order to have good growth from the beginning. Secondly, rotation age should be planned to end at or before the latter growth retardation stage.

Site index A species-specific measure of actual or potential forest productivity (site quality, usually for even-aged stands), expressed in terms of the average height of trees included in a specified stand component (defined as a certain number of dominants, co-dominants, or the largest and tallest trees per unit area) at a specified index or base age (SAF). As pertains to forested trust lands management by DNR, the index age is usually 50 or 100 years at breast or stump height for conifers and 20 years for red alder. Site indices may be grouped into site classes.

Site productivity class A species-specific classification of forest land in terms of inherent capacity to grow crops of industrial, commercial wood –*note* the site productivity class is usually derived from the site index (SAF). See also—site quality.

Site quality (a.k.a., site productivity) The productive capacity of a site, usually expressed as volume production of a given species (SAF).

Skidding The act of dragging a log or felled tree with a tractor (skidder) to a landing where it will be loaded onto a truck. See also yarding.

Snag A standing dead tree.

Softwood The xylem and trees of Gymnospermae –*note1.* commercial softwood timbers are practically confined to the order Coniferales (SAF). Compare to—hardwood.

Spacing – top height ratio (STH) A measure of intra-stand competition (useful to determine the preferred range for thinning for various species) that is the ratio between average top height and tree spacing. STH correlates directly to RD for stand tree heights of constant height-diameter ratio. The RD that corresponds to a particular STH is calculated by dividing SBA by the square root of: the SBA multiplied by 12 and divided by trees per acre. STH may be preferred over RD in pre-commercial stands because of ease of taking fixed versus variable radius plots.

Species The main category of taxonomic classification into which genera are subdivided, comprising a group of similar interbreeding individuals sharing a common morphology, physiology, and reproductive process –*note 1.* there is generally a sterility barrier between species, or at least reduced fertility in interspecific hybrids –*note 2.* the species is the basic unit of taxonomy on which

the binomial system has been established; the lower taxonomic hierarchy is species, sub-species, variety, and forma (SAF).

Spotted owl management area (SOMU) is a landscape-sized area, originally identical to the associated watershed administrative unit (WAU), in which DNR's HCP for forested trust lands requires management for sub-mature or dispersal habitat.

Stand As pertains to DNR management of forested trust lands and defined in DNR's HCP for forested trust lands, a group of trees that possess sufficient uniformity in composition, structure, age, spatial arrangement, or condition to distinguish them from adjacent groups. (One should also consider FMU objectives when delineating a stand; often the term stand is therefore interchangeable with the term FMU.) Compare to—cohort.

Stand assessment See—assessment

Stand basal area (SBA) BA averaged over a specified or implied unit of area (such as acre).

Stand density index (SDI) 1. a widely used measure developed by Reineke (1933) that expresses relative stand density in terms of the relationship of a number of trees to stand quadratic mean diameter 2. any index that expresses relative stand density based on a comparison of measured stand values with some standard condition (SAF). See also relative density (RD).

Stand exam See—assessment

Stand initiation As pertains to DNR management of forested trust lands and as defined in DNR's HCP for forested trust lands, is the first stage of forest growth; an open condition and new regeneration.

Stand simulator An equation-based automated growth and yield table that will generate future stand output projections in relation to inputs of current stand parameters. Examples of stand simulators are FVS, DNR-IMPS, Organon, and Tipsy. Synonym – growth and yield simulator.

Stem The principal axis of a plant from which buds and shoots develop (SAF).

Stocking . . . an indication of growing space occupancy relative to a preestablished standard (SAF). [Ed. note—DNR generally measures stocking as square feet of basal area per acre for commercial stands and as trees per acre for pre-commercial stands; stocking measures only space occupancy, and does not fully measure intra-stand competition. DNR measures competition within stands in terms of RD for commercial and spacing – top height ratio (STH) for pre-commercial stands]

Sub-mature habitat As pertains to DNR management of forested trust lands and as defined in DNR's HCP for forested trust lands, is habitat for the northern spotted owl to be perpetuated over at least 50 percent of each NRF management area.
Threshold targets east of Cascades:

- forest community composed of at least 40 percent Douglas-fir and grand fir
- canopy closure of at least 70 percent
- 110 to 260 trees per acre
- tree height or vertical density with either (a) dominant and co-dominant trees at least 90 feet tall, and/or (b) two or more canopy layers, numerous intermediate trees, numerous low perches
- snags/cavity trees or mistletoe infection with either (a) three or more snags or cavity trees per acre that are 20 or more inches at DBH, and/or (b) a moderate to high infection of mistletoe
- five percent ground cover of dead and down wood averaged over a stand.

Threshold targets west of Cascades:

- forest community dominated by conifers, or in mixed hardwood/conifer forest, the community is composed of at least 30 percent conifers (measured as trees per acre of dominant, codominant, and intermediate trees)
- at least 70 percent canopy closure
- 115 to 280 trees per acre that are at least 4 inches DBH
- height of dominant and codominant trees at least 85 feet
- at least three snags or cavity trees per acre 20 inches or more in DBH
- at least 5 percent ground cover of large down woody debris

Sub-mature management area As pertains to DNR management of forested trust lands and defined in DNR's HCP for forested trust lands, a SOMU that will be managed so that sub-mature habitat (or better) for the northern spotted owl is perpetuated over at least 50 percent of the management area.

Suppressed—See overtopped.

Sustainable harvest calculation (SHC) As pertains to DNR management of forested trust lands, a strategic analysis process that quantifies forestry goals, such as future forest conditions and trust revenue, against forecasted near and long-term effects of alternative sets of policy. This process is also used to recommend to the Board of Natural Resources the next decade's sustainable timber harvest level. DNR is required by law (RCW 79.10.320) to periodically calculate and adjust the harvest level from forest lands managed by DNR.

Sustainable harvest implementation process (SHIP) As pertains to DNR management of forested trust lands, is the process whereby management area strategies are developed that link the Department's forest management policies to stand-level prescriptions. The process apportions timber harvests and other silvicultural treatments over landscapes and time and thereby enables forest managers to achieve landscape environmental, economic, and social goals through efficient and effective implementation of Department policies.

Tending As pertains to DNR management of forested trust lands, a non-commercial forest stand activity that occurs after the free-to-grow stage. Tending includes, but is not limited to, pre-commercial thinning, fertilization, pruning, and pest treatments. Tending is undertaken to enhance

attainment of FMU objectives and usually requires financial analysis at a stand or landscape level to assess and justify return on investment.

Threshold targets As pertains to DNR management of forested trust lands, are arrays of one or more discrete and measurable stand attributes that as an aggregate constitutes an objective. For example, a FMU objective to "attain sub-mature habitat"[6] disassembles (for westside) into threshold targets of "115 to 280 trees per acre" of "at least 4 inches DBH," "dominant and co-dominant trees at least 85 feet tall," "canopy closure of at least 70 percent," "at least 3 snags per acre that are at least 20 inches DBH," and "a minimum of 5 percent ground cover of large down woody debris." When we know the threshold targets of an objective, we can model the time required for attainment. Once all threshold targets of a FMU objective are met, the objective is attained, and the FMU enters the FMU objective window. Similarly, objectives for activities as well as for areas larger than FMUs also have one or more threshold targets. For example, a NRF-designated spotted owl management area will have a threshold target to meet stand requirements for sub-mature habitat over at least 50 percent of its area. An activity of, say, pre-commercial thinning, may have only one threshold target: to reduce stocking of viable crop trees to 300 per acre.

Thinning As pertains to DNR management of forested trust lands, selective removal of trees against measurable, prescribed criteria, in order to improve and or accelerate attainment of FMU objectives. DNR categorizes thinnings as PCT, PCT-R, and commercial thinning (CT). In addition, VDT is thinning that varies stand density and promotes canopy diversification to achieve specified wildlife habitat values. The Society of American Foresters' Dictionary of Forestry defines thinning as "a cultural treatment made to reduce stand density of trees primarily to improve growth, enhance forest health, or recover potential mortality."

Timber Stands or individual trees that are potentially usable for veneer, lumber, or commercial poles.

Timber sale As pertains to DNR management of forested trust lands, is a sale of timber from forested trust land that is separate from the land. Except as provided by law, sales are at public auction in sealed bid. Oral auctions are allowed when DNR determines appropriate. Timber is usually required to be paid for as lump sum according to a pre-sale cruise multiplied by the purchaser's bid price or gradually as timber is harvested, hauled, and scaled upon which the scaled volume is multiplied by the purchaser's bid price.

Time value of money (TVM) The accrual value over time of capital. Examples of parameters used to express TVM are NPV, BLV, EAE, and internal rate of return (IRR).

Tractor A powered vehicle mounted on crawler tracks or wheels that is used for skidding, earth movement (with a solid blade), ripping (with a ripper blade or rear-mounted ripper teeth), or other similar uses.

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[6] The description of sub-mature NRF is from the HCP, page IV-12. The threshold target of "at least 70 percent canopy closure" is currently translated as "a Curtis' RD of at least 50," in order to enable forest sampling and statistical analysis of field data.

Tree A woody perennial plant, typically large and with a well-defined stem or stems carrying a more or less definite crown (SAF).

Trust A fiduciary relationship (created by a settlor) with respect to property, in which the person by whom the title to the property is held (the trustee) is subject to equitable duties to keep or use the property for the benefit of another (the trust beneficiary). A trust imposes numerous enforceable provisions and emplaces on the relationship the duty to act with utmost honesty and candor and solely in the interest of the trust beneficiaries.[7] For the state of Washington, the Enabling Act of February 22, 1889 conveyed the intent of Congress (the settlor) to establish a trust. Through this act, Congress conveyed title to land (the trust property) to the state Legislature (the trustee) for specifically identified beneficiaries (the trusts) such as, common schools, universities, normal schools, etc. The Legislature has further enacted that DNR is the agent who manages the trust property. See also – trust mandate.

Trust mandate is the DNR's legal duty to produce long-term income for the trust beneficiaries. The trust mandate is grounded in four tenets: the prudent person doctrine, undivided loyalty to the trusts, intergenerational equity versus maximizing current income, and avoiding foreclosing future options. Although it is the original and basic reason for DNR managing trust lands, the trust mandate must be implemented with respect to other applicable laws and rules as well.

Turn The logs yarded or skidded to the landing with a single trip of the skidder, shovel, carriage, butt rigging, or other logging equipment.

Understory All forest vegetation growing under an overstory (SAF).

Valuable material As defined in RCW 79.02.010, is any product or material on [public] lands, such as forest products, forage, or agricultural crops, stone, gravel, sand, peat, and all other materials of value (except mineral, coal, petroleum, and gas, as provided for under RCW 79.14). Furthermore, per RCW 79.15.010, valuable materials may be sold separately from the land when in the state's best interest to do so (as determined by DNR), but may not be sold for less than appraised value.

Variable density thinning (VDT) As pertains to DNR management of forested trust lands, thinning that combines financial and tree growth benefits with enhancements to wildlife habitat. VDT uses varied FMU densities to emulate what research indicates pre-European stand mosaics conducive to the northern spotted owl and many other forms of wildlife looked like. VDT is generally a part of a Biodiversity Pathways silvicultural prescription. A baseline stand mosaic recommended by Andrew Carey (USDA-Forest Service scientist) as conducive to viable spotted owl populations is on a scale of ½ to 1 acre and has:

- Around 15% of the stand area in small openings (RD near zero) and un-thinned patches (RD 60+) and thus provides for present and future thickets for cover;

[7] Paraphrased from p.2 in Souder, Jon A. and Sally K. Fairfax. 1998. State Trust Lands: History, Management, and Sustainable Use. University Press, Lawrence, KS.

- Around 85% of the stand area in 1:1 to 2:1 proportions between two RDs 5 to 7 points on either side of the desired stand average (i.e., a 10 to 15 point spread) to provide thermal and hiding cover. Suppressed shade tolerant understory trees and/or hardwoods are retained to provide hunting roosts and multi-canopy cover;
- LWD and snags/snag candidates should be present throughout the stand. Snags provide nesting cavities while LWD are a growth medium for truffles, a primary food source for the northern flying squirrel, in turn a primary prey for the northern spotted owl.

Variable radius plot As pertains to DNR management of forested trust lands, a plot sampling method where trees are selected with a probability proportional to their individual DBHs. This means that the larger the DBH of the tree, the more likely it is the tree will be sampled. Each tree is assumed to have it's own fixed radius plot with the tree at the center of the plot and the radius determined by the trees diameter. The tree is "in" if the variable plot center is within the tree's plot. The tree is "out" if the variable plot center is outside of the tree's plot.

Vegetation series (for most forestry purposes, identical to the term zone) Broad categories of natural plant communities occurring over large and often contiguous areas. They are named after the theoretical climax' most shade tolerant tree species that will eventually grow into dominance on the site.

Yarding The act of moving logs to the landing.

APPENDIX B—Integrated Pest Management

Integrated pest management (IPM) is managing forest stands so that they are unattractive to excessive insect and disease pests by using the situationally best of preventive, reactive, manual, chemical, or biological means. This section will list insects and diseases common to commercial tree species and preventive measures that have proven useful. The Pacific Northwest's most authoritative website for forest insect and disease pests is the USDA-Forest Service, Region 6, Forest Insect and Disease office at http://www.fs.fed.us/r6/nr/fid/wid.shtml. Alternatively, the Canadian Forest Service website, for diseases only, is http://www.pfc.cfs.nrcan.gc.ca/diseases/CTD/index_e.html. Additional, or more direct, links are listed after each disease or insect, below.

Needlecasts in Douglas-fir. Douglas-fir is susceptible to **Swiss needlecast** as well as other needlecasts such as ***Rhabdocline***. Needlecasts cause pre-mature shedding of all but the current year's foliage and gives the tree a distinctly thin-crowned, grayish, and often chlorotic appearance. Although not a direct killing agent, needlecasts often reduce annual growth by as much as 35 percent and also increase susceptibility to other pathogens, such as root rots. Susceptibility and risk are mitigated by inclusion of western hemlock, western redcedar, various true firs, and/or red alder. For further information, see: http://www.cof.orst.edu/cof/pub/home/rc/RC30.pdf, http://www.fs.fed.us/r6/nr/fid/mgmtnote/swissnc.pdf, and http://www.fs.fed.us/r6/nr/fid/mgmtnote/rhabdo.pdf.

Root Rots in Douglas-fir. Douglas-fir is highly vulnerable to *Phellinus (Poria) weirii*, **laminated root rot**. It lingers in a viable, infectious form in old root systems for more than 80 years following clearcutting. Phellinus may be recognized as having stand infection centers with fallen Douglas-fir without root wads; as one moves outward from the infection center, symptoms gradually subside. *Phellinus* is financially infeasible to eradicate and is best treated by clearcutting at least one tree length beyond outermost visible trace symptoms (chlorosis or thinning crowns) and reforesting with red alder (immune) or western redcedar (highly resistant). For further information, see: http://www.fs.fed.us/r6/nr/fid/fidls/fidl159.htm.

Other Root Rots in Conifers. Douglas-fir, western and mountain hemlock, pines, and true firs are susceptible to **red ring rot** (aka **honeycomb rot, white pocket rot, or white pitted rot),** caused by the fungus *Phellinus (Fomes) pini*. It is the most common stem decay of conifers in the Pacific Northwest. The perennial conks are distinctly "hoof-shaped" to bracket-like, often emerging from knots or branch stubs. The upper surfaces of conks are rough, dull gray to brownish black with concentric furrows paralleling the lighter colored margin. The lower surface is a rich brown color with small circular pores. This disease spreads by wind-carried spores that germinate on wounds and branch stubs. Prevention includes establishment of stands that include intermingled significant components of western redcedar and red alder and not scarring leave trees in harvest. Anecdotal references to leaving branch stubs long enough to compartmentalize the pathogen in the stub and managing for tree vigor also exist. Reactive management involves salvaging infected trees before excessive merchantability is lost (increasing amounts of decay within the tree is indicated by more and larger conks). For further information see: http://www.pfc.forestry.ca/diseases/CTD/Group/Heart/heart13_e.html,

http://www.fs.fed.us/r6/nr/fid/mgmtnote/redring.pdf, and
http://www.fs.fed.us/r6/rogue/swofidsc/stemdecay/redringrot.html.

Bear Damage. Douglas-fir and western redcedar are susceptible to **bear damage**, particularly in the free-to-grow to sub-merchantable age bracket. Damage usually occurs in the spring when Douglas-fir sap is an attractive food source. The best prevention is species diversity; bears often develop a taste for Douglas-fir sap when plentiful and easy to get. In cases where FMU objectives dictate Douglas-fir as a final crop but shade tolerant species are ecologically adapted, consider that full stocking at age 60 is only 100 to 150 trees per acre for Douglas-fir. An initial site-adapted species mixture of 150 Douglas-fir and 250 western hemlock per acre allows targeted stocking with Douglas-fir at final harvest and the preponderance of western hemlock will make the FMU less apt to attract bears than a FMU with pure Douglas-fir or western redcedar. In addition, the Washington department of Fish and Wildlife has as standard operating procedure to cooperate with land owners to reduce bear damage. To that end, local agents may cooperate with department foresters in allowing specific bears to be taken under so-called depredation permits.

Tip Weevil. Sitka spruce is susceptible to the **white pine weevil** (previously known as the **Sitka spruce weevil**). The insect lays its eggs on the terminal shoot. Larvae mine the phloem and girdle the leader, causing it to die and curl. Damaged trees are often overtopped and suppressed by other species. Surviving spruce may be crooked, bushy or low value. These weevils require relatively high temperatures to thrive. Areas immediately adjacent to the coast are low hazard due to cool climate. In warmer sites, attacks commonly begin five years after planting, when leaders become large enough to attract weevils. Many damaged trees develop multiple tops, which may be attacked annually. Weevil populations and attack rates stabilize when average plantation heights are between 2 and 10 m, and then begin to decline when tree height is >10 m. Severe infestations have an average of 30 percent or more attacked leaders per year. The spruce weevil is not a problem in older stands.

FMUs spaced at low densities at an early age are at increased risk from weevil attack, because more vigorously growing trees produce longer, thicker leaders, which in turn provide better nutrition for the weevil. While high levels of weevil attack are also observed in high density FMUs, the resulting defect is generally less severe due to the reduced branching in tightly spaced trees. For further information, see:
http://www.fs.fed.us/r6/nr/fid/widweb/wid-twig.shtml#twig-4,
http://www.pfc.cfs.nrcan.gc.ca/diseases/hforest/Pests/spweevil_e.html, and
http://www.forestry.ubc.ca/fetch21/FRST308/lab4/pissodes_strobi/sitka.html.

Weevil-resistant Sitka spruce seedlings are becoming available from the Canadian Forest Service. Contact the DNR seed collection and storage operation (360-664-2174) or the DNR seed orchard (360-407-7578) for further information, and keep in mind the department plants only stock which is naturally site-adapted in order to preserve the natural gene pool.

Spruce Aphid. Sitka spruce is periodically defoliated by the **spruce aphid**, *Elatobium abietina*, believed to have been introduced from Europe. The spruce aphid causes premature loss of older foliage. Repeated years of defoliation can cause growth loss, branch die-back, and tree death.

Usually buds are unaffected, so new growth flushes normally. Although aphids are present year round, mild winter temperatures can allow dramatic population increases in February and March. In May and June, damaged needles turn completely brown and drop off the tree. Insecticides are used to control spruce aphids on ornamental trees and Christmas trees, but not forest trees. Avoid fertilizing spruce, since the increased nitrogen content in foliage may result in greater aphid fecundity. For further information, see:
http://www.for.gov.bc.ca/hfp/forsite/pest_field_guide/Green_spruce_aphid.htm,
http://www.forestry.ubc.ca/fetch21/FRST308/lab5/elatobium_abietinum/aphid.html, and
http://www.fs.fed.us/r6/nr/fid/widweb/wid-suck.shtml#suck-5.

Balsam Wooly Adelgid. True fir (*Abies*) species are affected by the exotic aphid-like insect **balsam woolly adelgid** (BWA), *Adelges piceae*. Sub-alpine fir, Pacific silver fir, and grand fir are frequently attacked throughout their natural ranges. BWA infestations can develop in off-site plantings of noble fir, but little damage has been observed in its native range. BWA infested grand fir have suffered few direct effects from BWA, but greater than expected damage from drought (Puget Sound) and the defoliator western spruce budworm (east Cascades). Although it has been present in Washington several decades, and initially caused mortality on thousands of acres, BWA has not yet fully colonized all susceptible sites nor fully exhausted the resistance of partially susceptible individuals. More damage is expected. Harvest true fir infested with BWA and plant non-host trees appropriate for the site. Discriminate against infested fir when thinning mixed stands. True fir cone collections should be restricted to trees with no symptoms of BWA infestation. For further information, see:
http://www.pfc.cfs.nrcan.gc.ca/diseases/hforest/Pests/bwaphid_e.html,
http://www.forestry.ubc.ca/fetch21/FRST308/lab4/adelges_piceae/balsam.html , and
http://www.fs.fed.us/r6/nr/fid/widweb/wid-suck.shtml#suck-5.

Annosus Root Rot. Western hemlock, and to lesser extents, other conifer white-woods, are susceptible to *Heterobasidion (Fomes) annosum*, also known as **annosus root rot**. Annosus root rot produces a dark brown conk and brown-heart rot. It spreads through both spores and root grafts. Spore propagation prefers live bare wood i.e., fresh stump surfaces or logging damage to stem bark, to germinate. Serious, stand-level damage from annosus root rot occurs when the rot has migrated from the stem or stump of original infection through the roots to where they graft with roots of live trees. However, Annosus is slow growing, and more aggressive non-pathogenic fungi, may out-compete and eventually exclude it. Stumps tall enough to allow monopolization by these faster-growing fungi will therefore reduce damage by annosus root rot to acceptable levels if rotations are not excessively long. Prescription: Cut white-wood stumps 12 inches or taller and keep rotations less than 100 years. Also, mix in more resistant species such as Douglas-fir, western redcedar, and red alder. For further information, see:
http://www.pfc.cfs.nrcan.gc.ca/diseases/CTD/Group/Root/root3_e.html,
http://www.pfc.cfs.nrcan.gc.ca/pathology/rootd/annosus_e.html, and
http://www.fs.fed.us/r6/nr/fid/widweb/wid-rd.shtml#rd-1.

Hemlock Dwarf Mistletoe. Western hemlock is susceptible to **dwarf mistletoe**, a parasitic plant (*Arceuthobium tsugense*) that adheres to branches and stems. Seeds are sticky and forcibly discharged as far a 60 ft from fruits in the fall. Spread is most rapid in multi-storied stands;

spread in single storied stands averages 1 meter per year. Severe infestations cause growth loss, reductions in wood quality, mortality and exceptional nesting platforms for the marbled murrelet. Damage is more serious in stands over 100 years of age than in younger stands. To reduce the parasite to endemic levels, clearcut severely infested sites, and remove severely infected trees in lightly infested stands. Douglas-fir and western redcedar are immune to the parasite that infects western hemlock. For further information, see: http://www.fs.fed.us/r6/nr/fid/widweb/wid-mt.shtml#mist-3, and http://www.fs.fed.us/r6/nr/fid/fidls/hemlock-dm.pdf.

Hemlock Looper. Western hemlock is susceptible to epidemics of the **hemlock looper**, *Lambdina fiscellaria lugubrosa*, a defoliating caterpillar. Recent outbreaks have occurred only in Northwest region, but could conceivably occur in any westside locale. Hemlock looper outbreaks historically have occurred in overmature hemlock stands, but recently have occurred in 60 year old second growth. Outbreaks generally last three years, and can kill vast acres of stands dominated by western hemlock. Strong epidemics of hemlock looper and the associated insect phantom hemlock looper *Nepytia phantasmaria* (whose main hosts include Douglas-fir and western hemlock) often kill other incidental conifers as well. Recent anecdotal observations indicate that stands whose vigor has been enhanced by thinning are relatively resistant to surrounding epidemics. Diversity and high tree vigor at both FMU and landscape levels are useful in moderating outbreaks to within acceptable levels. For further information, see: http://www.fs.fed.us/r6/nr/fid/widweb/wid-def.shtml#def-16, http://www.pfc.cfs.nrcan.gc.ca/diseases/hforest/Pests/whlooper_e.html, and http://www.forestry.ubc.ca/fetch21/FRST308/lab5/lambdina_fiscellaria_lugubrosa/looper.html for the hemlock looper and http://www.pfc.forestry.ca/entomology/defoliators/loopers/phantom_e.html for the phantom hemlock looper.

White Pine Blister Rust. Western white pine is susceptible to a **blister rust** caused by the fungus *Cronartium ribicola*. This is the most serious pest of 5-needle pines in the Pacific Northwest. Alternate hosts include members of the genus *Ribes*. Diseased trees are identified by yellow/red needle spots; spindle shaped swellings on branches; dead patches along stem with greenish-yellow to orange margins; flagging of branches and tree tops. Reforest with resistant 5-needle planting stock; retain uninfected or lightly infected trees for seed sources. Bundle pruning contracts with bough sales to expeditiously eliminate the most susceptible lower branches. For further information, see: http://www.fs.fed.us/r6/nr/fid/widweb/wid-rust.shtml#rust-8, http://www.fs.fed.us/r6/nr/fid/mgmtnote/wpbr.pdf, http://www.na.fs.fed.us/spfo/pubs/howtos/ht_wpblister/toc.htm, and http://www.pfc.cfs.nrcan.gc.ca/diseases/CTD/Group/Rust/rust7_e.html

APPENDIX C – Relative Density and Quadratic Mean Diameter

Relationship of Basal Area & Trees/acre or Spacing to Relative Density

Basal Area	Tree/acre & Spacing																	
	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450
	42x42	30x30	24x24	21x21	19x19	17x17	16x16	15x15	14x14	13x13	13x13	12x12	12x12	11x11	11x11	10x10	10x10	10x10
40	10	11	13	14	14	15	16	16	17	17	18	18	18	19	19	19	20	20
60	13	16	17	19	20	21	21	22	23	23	24	24	25	25	26	26	27	27
80	16	19	21	23	24	25	26	27	28	29	30	30	31	31	32	33	33	33
100	19	23	25	27	29	30	31	32	33	34	35	36	36	37	38	38	39	40
120	22	26	29	31	33	34	36	37	38	39	40	41	42	43	43	44	45	45
140	25	29	33	35	37	39	40	42	43	44	45	46	47	48	49	49	50	51
160	27	33	36	39	41	43	44	46	47	49	50	51	52	53	54	55	56	56
180	30	36	39	42	45	47	49	50	52	53	54	56	57	58	59	60	61	62
200	32	38	43	46	48	51	53	54	56	57	59	60	61	63	64	65	66	67
220	35	41	46	49	52	54	56	58	60	62	63	64	66	67	68	69	70	71
240	37	44	49	52	55	58	60	62	64	66	67	69	70	72	73	74	75	76
260	39	47	52	56	59	62	64	66	68	70	72	73	75	76	77	79	80	81
280	42	49	55	59	62	65	68	70	72	74	76	77	79	80	82	83	84	86
300	44	52	58	62	66	69	71	74	76	78	80	82	83	85	86	88	89	90
320	46	55	61	65	69	72	75	77	80	82	84	86	87	89	90	92	93	95
340	48	57	63	68	72	75	78	81	83	86	88	90	91	93	95	96	98	99
360	50	60	66	71	75	79	82	84	87	89	91	93	95	97	99	100	102	103
380	52	62	69	74	78	82	85	88	91	93	95	97	99	101	103	105	106	108
400	54	65	72	77	81	85	88	91	94	97	99	101	103	105	107	109	110	112

Relationship of Basal Area & Trees/acre or Spacing to Quadratic Metric Diameter (Dq)

Basal Area	Tree/acre & Spacing																	
	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450
	42x42	30x30	24x24	21x21	19x19	17x17	16x16	15x15	14x14	13x13	13x13	12x12	12x12	11x11	11x11	10x10	10x10	10x10
40	17.1	12.1	9.9	8.6	7.7	7.0	6.5	6.1	5.7	5.4	5.2	4.9	4.8	4.6	4.4	4.3	4.2	4.0
60	21.0	14.8	12.1	10.5	9.4	8.6	7.9	7.4	7.0	6.6	6.3	6.1	5.8	5.6	5.4	5.2	5.1	4.9
80	24.2	17.1	14.0	12.1	10.8	9.9	9.2	8.6	8.1	7.7	7.3	7.0	6.7	6.5	6.3	6.1	5.9	5.7
100	27.1	19.1	15.6	13.5	12.1	11.1	10.2	9.6	9.0	8.6	8.2	7.8	7.5	7.2	7.0	6.8	6.6	6.4
120	29.7	21.0	17.1	14.8	13.3	12.1	11.2	10.5	9.9	9.4	8.9	8.6	8.2	7.9	7.7	7.4	7.2	7.0
140	32.0	22.7	18.5	16.0	14.3	13.1	12.1	11.3	10.7	10.1	9.7	9.3	8.9	8.6	8.3	8.0	7.8	7.6
160	34.3	24.2	19.8	17.1	15.3	14.0	12.9	12.1	11.4	10.8	10.3	9.9	9.5	9.2	8.8	8.6	8.3	8.1
180	36.3	25.7	21.0	18.2	16.2	14.8	13.7	12.8	12.1	11.5	11.0	10.5	10.1	9.7	9.4	9.1	8.8	8.6
200	38.3	27.1	22.1	19.1	17.1	15.6	14.5	13.5	12.8	12.1	11.5	11.1	10.6	10.2	9.9	9.6	9.3	9.0
220	40.2	28.4	23.2	20.1	18.0	16.4	15.2	14.2	13.4	12.7	12.1	11.6	11.1	10.7	10.4	10.0	9.7	9.5
240	42.0	29.7	24.2	21.0	18.8	17.1	15.9	14.8	14.0	13.3	12.6	12.1	11.6	11.2	10.8	10.5	10.2	9.9
260	43.7	30.9	25.2	21.8	19.5	17.8	16.5	15.4	14.6	13.8	13.2	12.6	12.1	11.7	11.3	10.9	10.6	10.3
280	45.3	32.0	26.2	22.7	20.3	18.5	17.1	16.0	15.1	14.3	13.7	13.1	12.6	12.1	11.7	11.3	11.0	10.7
300	46.9	33.2	27.1	23.5	21.0	19.1	17.7	16.6	15.6	14.8	14.1	13.5	13.0	12.5	12.1	11.7	11.4	11.1
320	48.4	34.3	28.0	24.2	21.7	19.8	18.3	17.1	16.1	15.3	14.6	14.0	13.4	12.9	12.5	12.1	11.7	11.4
340	49.9	35.3	28.8	25.0	22.3	20.4	18.9	17.7	16.6	15.8	15.1	14.4	13.8	13.3	12.9	12.5	12.1	11.8
360	51.4	36.3	29.7	25.7	23.0	21.0	19.4	18.2	17.1	16.2	15.5	14.8	14.3	13.7	13.3	12.8	12.5	12.1
380	52.8	37.3	30.5	26.4	23.6	21.6	20.0	18.7	17.6	16.7	15.9	15.2	14.6	14.1	13.6	13.2	12.8	12.4
400	54.2	38.3	31.3	27.1	24.2	22.1	20.5	19.1	18.1	17.1	16.3	15.6	15.0	14.5	14.0	13.5	13.1	12.8

APPENDIX D – Site Index Tables

DOUGLAS FIR
50-YEAR SITE INDEX TABLE

State of Washington — Department of Natural Resources
Application: Western Washington
Source: James King

Breast Height Age	Site Index (top)/Site Class (bottom)									
	60	70	80	90	100	110	120	130	140	150
	V		IV		III		II		I	
6	10.7	11.8	12.9	14.1	15.2	16.5	17.8	19.1	20.5	21.9
8	13.1	14.7	16.3	18.0	19.7	21.5	23.3	25.2	27.2	29.1
10	15.7	17.8	20.0	22.3	24.5	26.8	29.2	31.6	34.1	36.6
12	18.7	21.4	24.1	26.9	29.7	32.5	35.4	38.3	41.3	44.3
14	21.7	24.9	28.2	31.5	34.7	38.1	41.5	44.9	48.3	51.8
16	24.7	28.4	32.1	35.9	39.7	43.5	47.4	51.3	55.2	59.2
18	27.5	31.7	36.0	40.3	44.5	48.8	53.1	57.4	61.8	66.2
20	30.3	35.0	39.7	44.4	49.1	53.9	58.6	63.4	68.2	73.0
22	32.9	38.1	43.3	48.4	53.6	58.8	64.0	69.2	74.4	79.7
24	35.5	41.0	46.7	52.3	57.8	63.5	69.1	74.7	80.3	86.0
26	37.9	43.9	49.9	55.9	61.9	68.0	74.0	80.0	86.0	92.1
28	40.2	46.6	53.1	59.5	65.9	72.3	78.7	85.1	91.5	97.9
30	42.4	49.3	56.1	62.9	69.7	76.4	83.2	90.0	96.8	103.5
32	44.5	51.8	58.9	66.1	73.3	80.4	87.5	94.7	101.8	109.0
34	46.6	54.1	61.7	69.2	76.8	84.2	91.7	99.3	106.7	114.3
36	48.5	56.4	64.3	72.2	80.1	87.9	95.8	103.6	111.4	119.3
38	50.4	58.6	66.8	75.0	83.2	91.4	99.6	107.8	116.0	124.1
40	52.2	60.7	69.3	77.8	86.3	94.8	103.3	111.9	120.4	128.8
42	53.9	62.7	71.6	80.4	89.3	98.1	106.9	115.7	124.6	133.4
44	55.5	64.6	73.8	83.0	92.1	101.3	110.4	119.5	128.6	137.7
46	57.0	66.5	76.0	85.4	94.8	104.3	113.7	123.1	132.5	142.0
48	58.5	68.3	78.0	87.7	97.4	107.2	116.9	126.6	136.3	146.0
50	60.0	70.0	80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0
52	61.4	71.6	81.9	92.1	102.4	112.7	122.9	133.2	143.5	153.8
54	62.7	73.2	83.7	94.3	104.7	115.3	125.8	136.4	147.0	157.5
56	64.0	74.7	85.5	96.2	107.0	117.8	128.6	139.4	150.2	161.1
58	65.2	76.2	87.2	98.2	109.2	120.2	131.3	142.4	153.4	164.5
60	66.4	77.6	88.8	100.1	111.3	122.6	133.9	145.2	156.5	167.9
62	67.5	79.0	90.4	101.9	113.4	124.9	136.4	148.0	159.6	171.1
64	68.6	80.3	91.9	103.6	115.3	127.1	138.8	150.6	162.5	174.3
66	69.7	81.5	93.4	105.3	117.2	129.2	141.2	153.2	165.3	177.4
68	70.7	82.8	94.8	106.9	119.1	131.3	143.4	155.7	168.0	180.4
70	71.7	83.9	96.2	108.5	120.9	133.2	145.7	158.2	170.7	183.3
72	72.6	85.1	97.6	110.0	122.6	135.2	147.8	160.6	173.3	186.1
74	73.6	86.2	98.8	111.5	124.3	137.1	149.9	162.8	175.8	188.8
76	74.5	87.2	100.1	113.0	125.9	138.9	151.9	165.0	178.2	191.4
78	75.3	88.3	101.3	114.4	127.5	140.6	153.9	167.2	180.6	194.0
80	76.2	89.3	102.5	115.7	129.0	142.4	155.8	169.3	182.9	196.5
82	77.0	90.3	103.6	117.0	130.5	144.0	157.6	171.3	185.2	199.0
84	77.8	91.2	104.7	118.3	131.9	145.6	159.4	173.3	187.3	201.4
86	78.5	92.1	105.8	119.5	133.3	147.2	161.2	175.3	189.4	203.7
88	79.2	93.0	106.8	120.7	134.7	148.8	162.9	177.2	191.5	206.0
90	80.0	93.9	107.8	121.9	136.0	150.2	164.5	179.0	193.5	208.2
92	80.7	94.7	108.8	123.0	137.3	151.7	166.2	180.8	195.5	210.3
94	81.3	95.5	109.8	124.1	138.6	153.1	167.7	182.5	197.4	212.4
96	82.0	96.3	110.7	125.2	139.8	154.5	169.3	184.3	199.3	214.5
98	82.6	97.1	111.6	126.2	141.0	155.8	170.8	185.9	201.1	216.5
100	83.2	97.8	112.5	127.2	142.1	157.1	172.2	187.5	202.9	218.4